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INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

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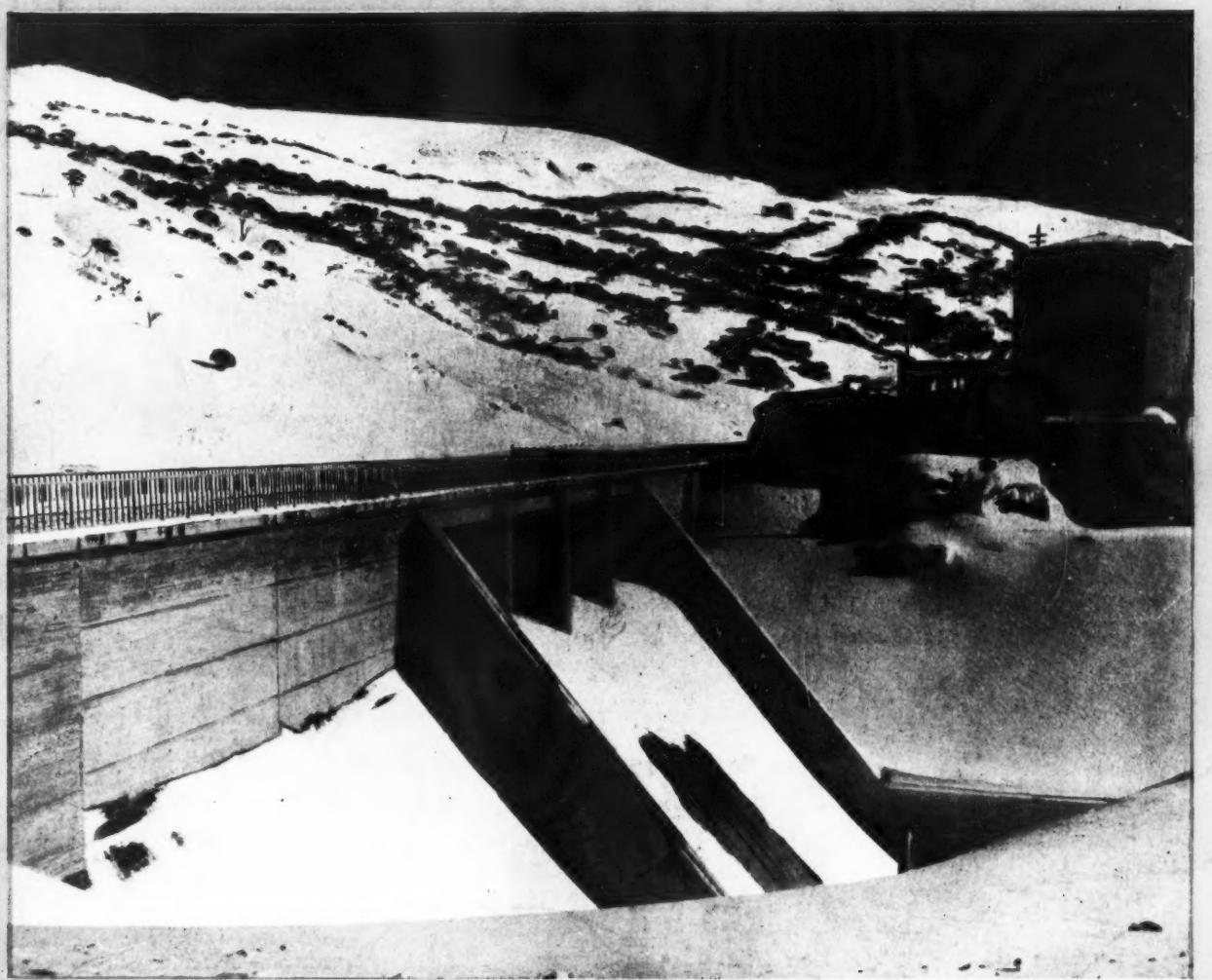

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EXCAVATORS
built for the toughest digging

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For the most punishing power shovel work—digging and loading rock—the P & H Model 955-A sets new records for speed and stamina. An outstanding example of advanced engineering, this excavator is equipped with the Magnetorque swing, which eliminates troublesome friction clutches—produces 20% faster—lasts the life of the machine. The P & H Model 955-A is a sound investment for big construction jobs, open pit mining and quarrying.

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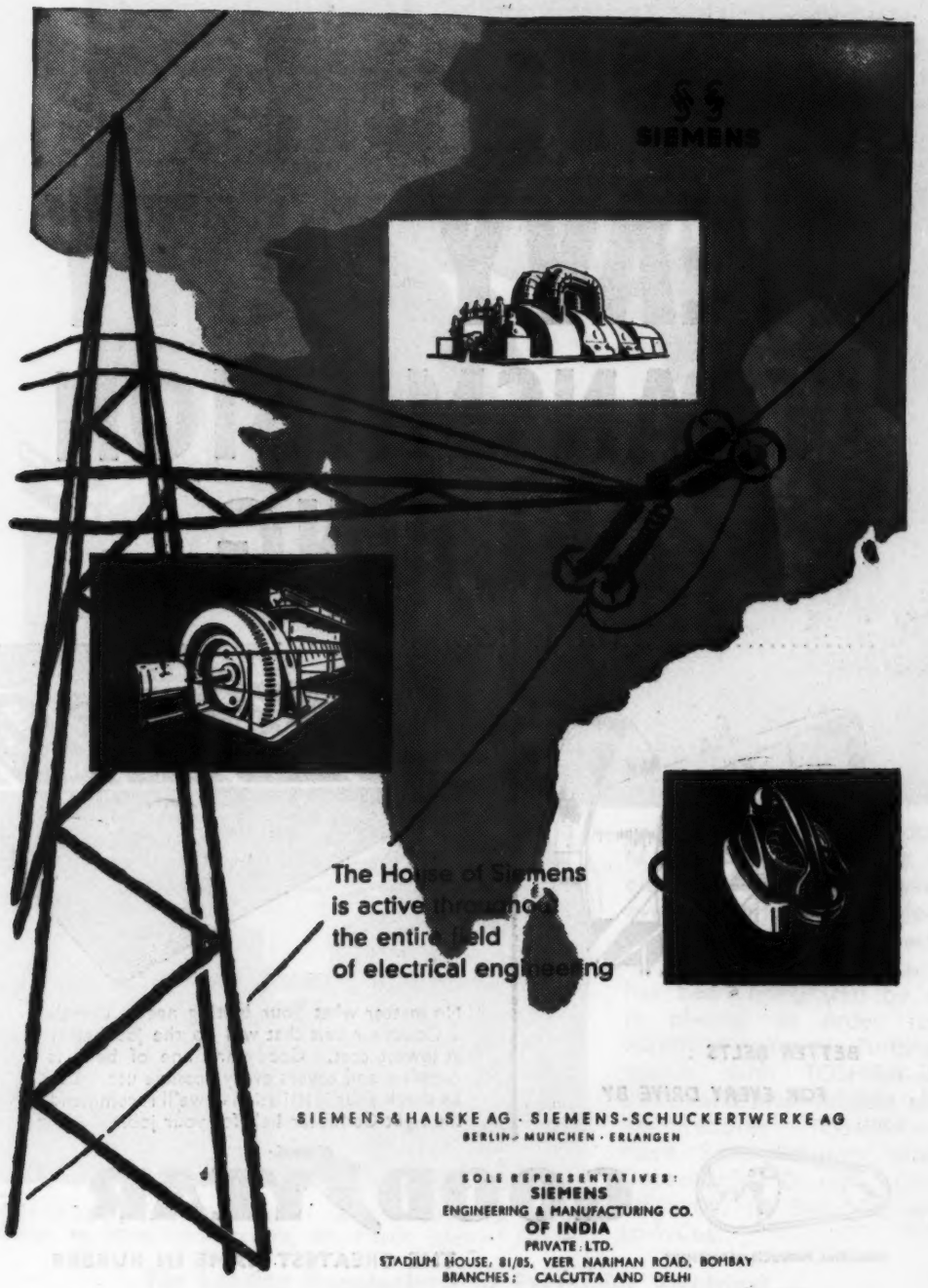

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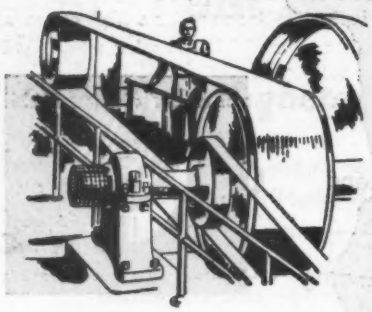
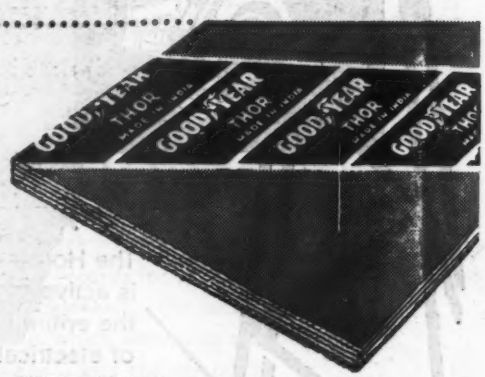


BETTER BELTS

FOR EVERY DRIVE BY



No matter what your belting needs, there's a Goodyear belt that will do the job better at lowest cost. Goodyear's line of belts is *complete* and covers every possible use. Let us check your installation — we'll recommend the *right* Goodyear belt for your job.

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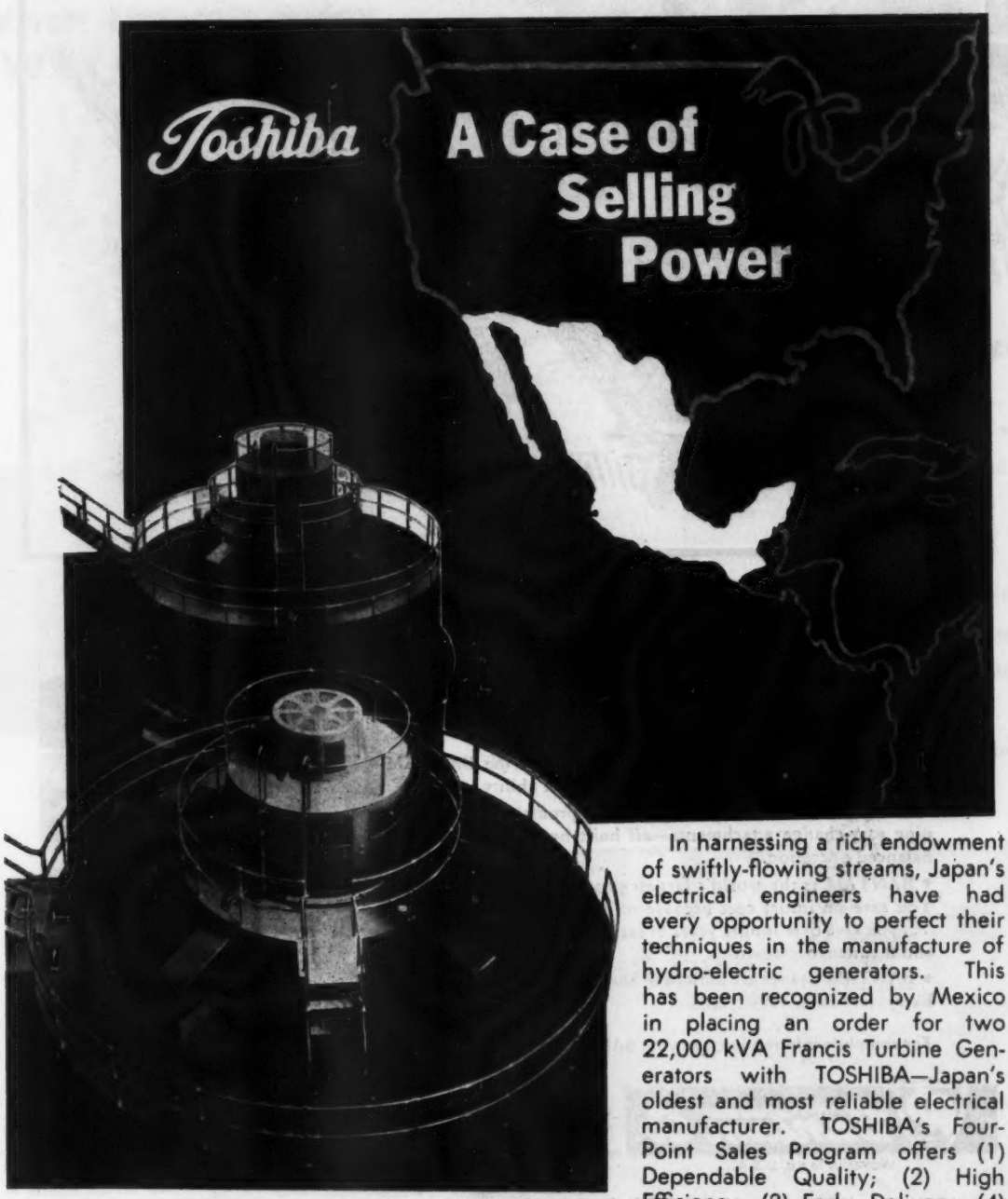

TOSHIBA, 45,000 kVA Francis Turbine Generators similar in design to those for Mexico's El Fuerte Power Station.

In harnessing a rich endowment of swiftly-flowing streams, Japan's electrical engineers have had every opportunity to perfect their techniques in the manufacture of hydro-electric generators. This has been recognized by Mexico in placing an order for two 22,000 kVA Francis Turbine Generators with TOSHIBA—Japan's oldest and most reliable electrical manufacturer. TOSHIBA's Four-Point Sales Program offers (1) Dependable Quality; (2) High Efficiency; (3) Early Delivery; (4) Low Cost.

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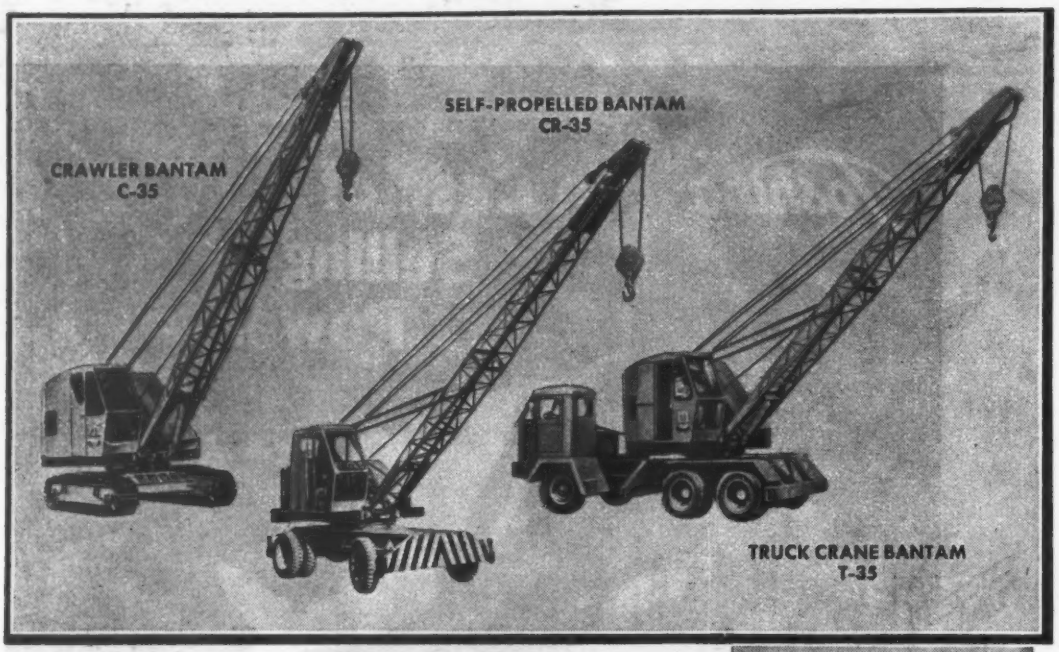
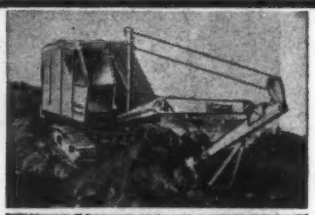
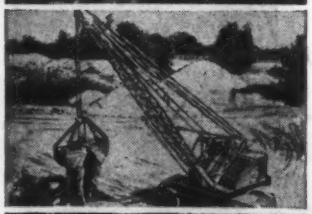


Now...the SCHIELD Bantam comes with a choice of 3 mountings





Only BANTAM in its popular sizes and capacities offers you a choice of truck, crawler or self-propelled mountings.

- Each is built by Schield Bantam strictly for the BANTAM—assuring matched performance, greater work ability.
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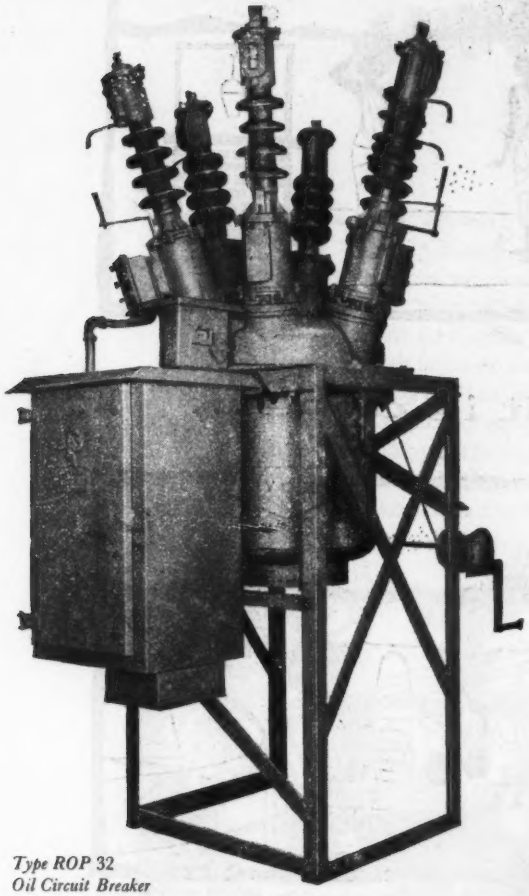
—the answer is

Ferguson Pailin



Type ROP 32
Oil Circuit Breaker

When the dam is built and the major constructional work completed the task of installing the electrical plant and the equipment must be undertaken.

Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

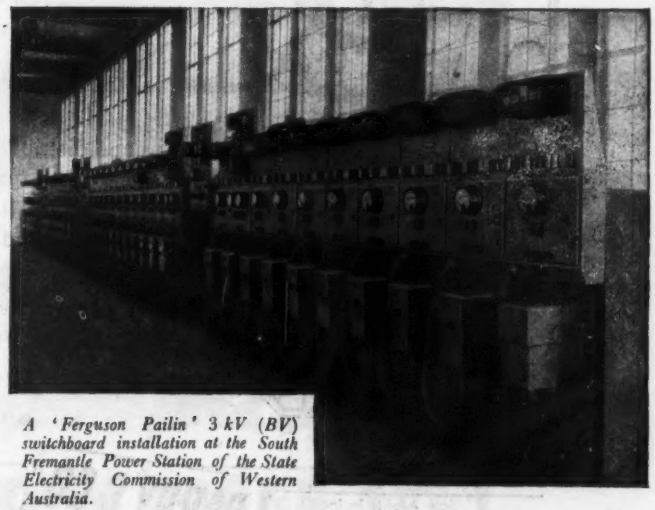
The versatility of the 'ROP 32' makes it remarkably adaptable to local requirements. Complete dependability and reliability make it a natural choice for incorporation into any scheme involving the transmission of power at 22 kV or 33 kV.

The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

'BV' SWITCHGEAR

'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

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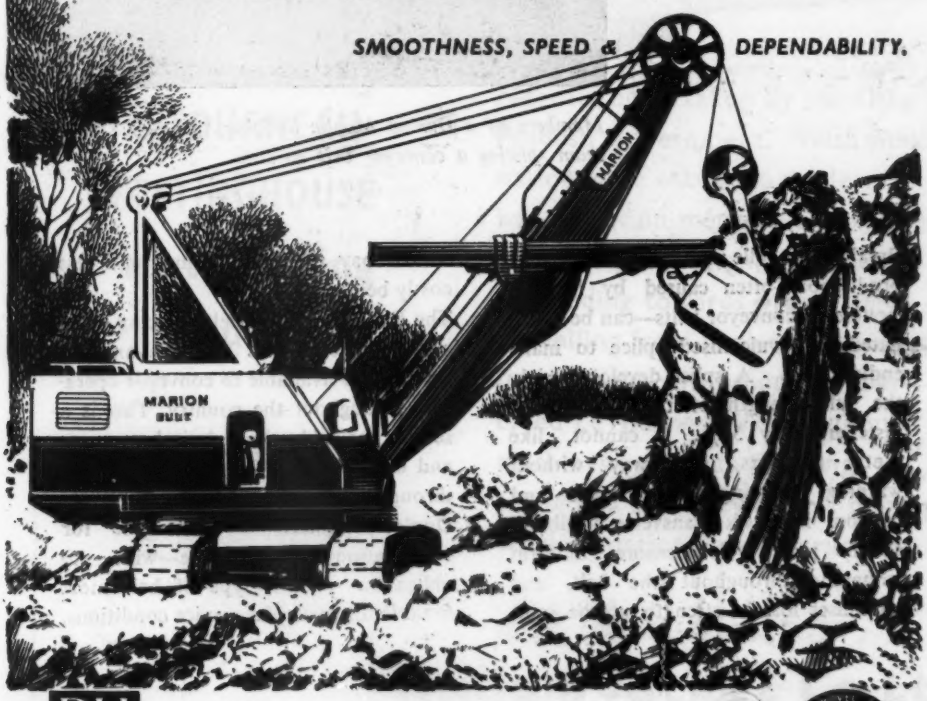
Big yardage jobs move quickly with the 111-M. Its diesel power is balanced with extra heavy design and construction.
Gentle air controls put this big machine into action with finger-tip control.
Theres a big cut, too, in excavation costs for many reasons.
One is the electric swing that results in faster cycle time and accurate spotting of the load without worry about over-heated swing clutches.
Ward-Leonard electric swing and Marion air control give

SMOOTHNESS, SPEED & DEPENDABILITY.



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MBG/10

NEWS FOR CONVEYOR BELT USERS

Members of a Dunlop Mobile Splicing team splicing a conveyor belt on site.

Breakdowns, idle man hours and loss of production—often caused by fastener trouble on conveyor belts—can be eliminated by a vulcanised splice to make endless belts. A splice develops nearly the full strength of the belt, metal fasteners only 50%. It cannot, like metal fasteners, give way without warning Splicing reduces noise and friction, increases transverse flexibility at the joint which ensures uniform troughing throughout the belt, and minimises loss of strength at the joint which may permit a thinner and less costly belt to be used.

The Dunlop Mobile Belt Splicing team splices belts endless on site and its services are available to conveyor operators throughout the country. This is a service backed by the technical resources and experience of Dunlop laboratories throughout the world.

Dunlop engineers are available for consultation and advice—with no obligation—on the type of belt most suitable for particular service conditions.

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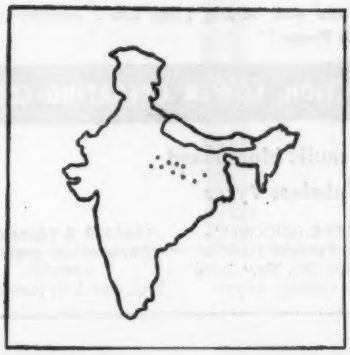
Four million yards of rock and earth moved in less than ten thousand hours. This is the proud contribution of 70 LeTourneau-Westinghouse mechanical earth-moving machines to the construction of five irrigation dams and many other reservoir and flood control projects

with LeTOURNEAU-WESTINGHOUSE earth-moving equipment

recently undertaken by the Uttar Pradesh Government. With similar nation-wide efforts to modernize her irrigation methods and increase her food production, India today is speeding towards prosperity. Travelling from project to project under their own power, rubber-tyred LeTourneau-Westinghouse machines are today bringing speed and efficiency to this mighty work of national reconstruction.



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WJC-264A

CAT

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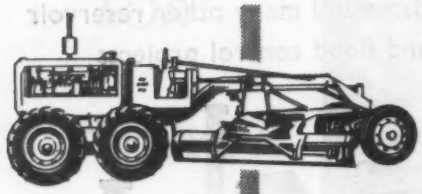
All over India on the big construction projects with municipalities ; state farms ; and with the leading contractors, you can see Caterpillar Motor Graders hard at work.

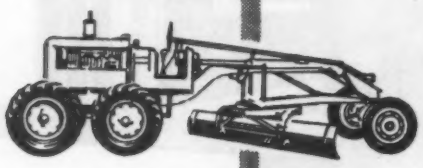
Building or maintaining existing roads, ditches, shaping banks, there is no tool like the profit making Caterpillar Motor Grader.

All over India, and throughout the world successful contractors and project engineers give Caterpillar their first choice. The main reasons for this preference are the proved low cost, high production and long-lived performance of these famous machines.

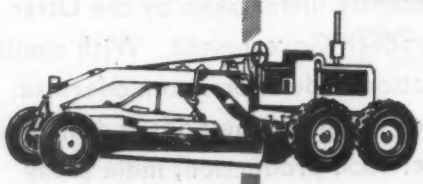
Ensure the job gets done to time by using a Caterpillar Motor Grader. There are three models the No. 12, 112 and 212. One of these, or more, is the answer to your problem.



No. 12—115 HP



No. 112—75 HP



No. 212—50 HP

CATERPILLAR*

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CAT MOTOR GRADER SPECIFICATIONS

	No. 12	No. 112	No. 212
Engine	Diesel, four-stroke cycle		
Blade range :			
Lift above ground	16"	15½"	14½"
Side shift (right or left) ...	40"	36"	33¾"
Maximum bank cutting angle ...	90°	90°	90°
Maximum shoulder reach (measured outside rear wheels) ...	7'4"	6'5"	5'

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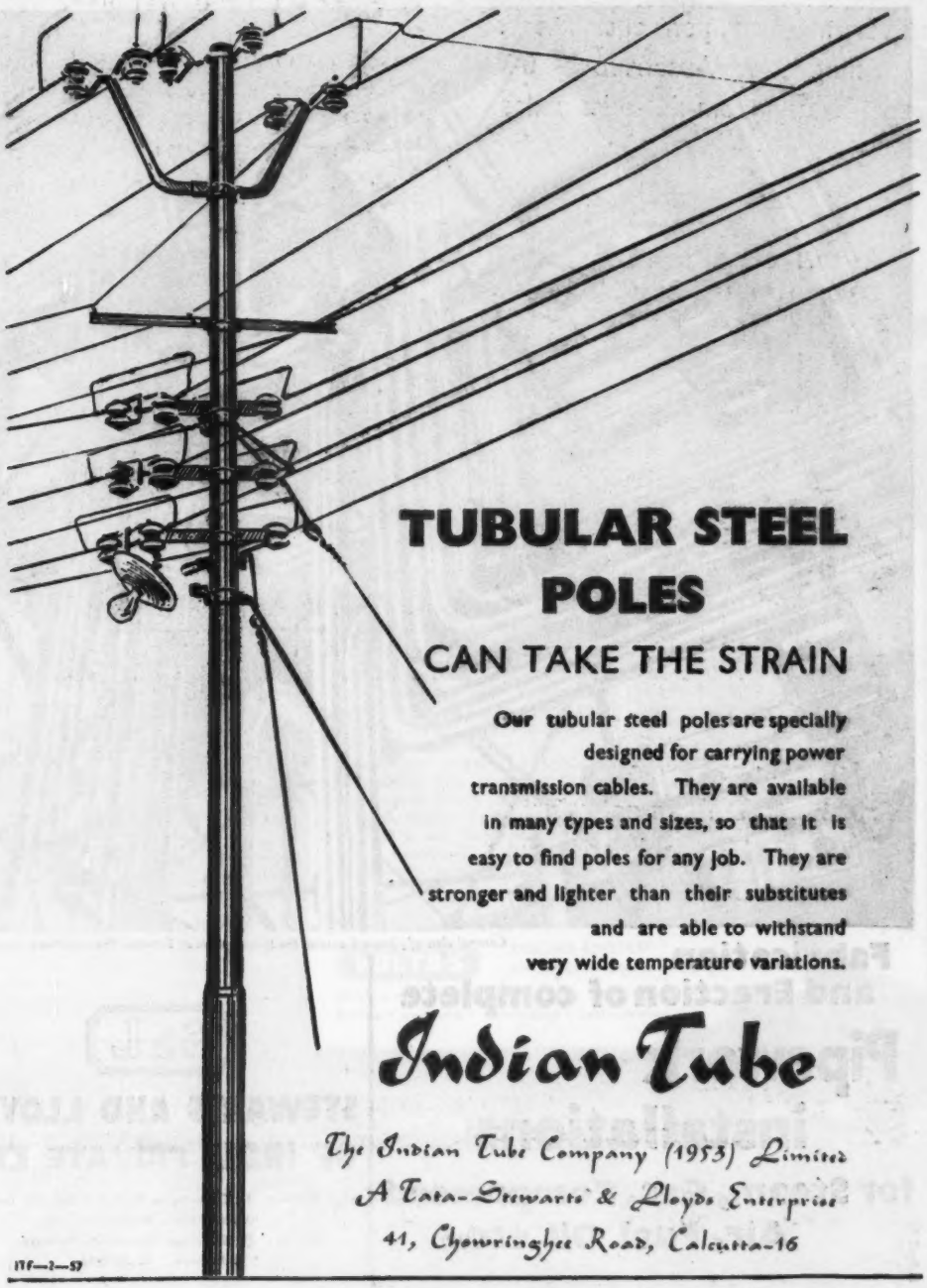

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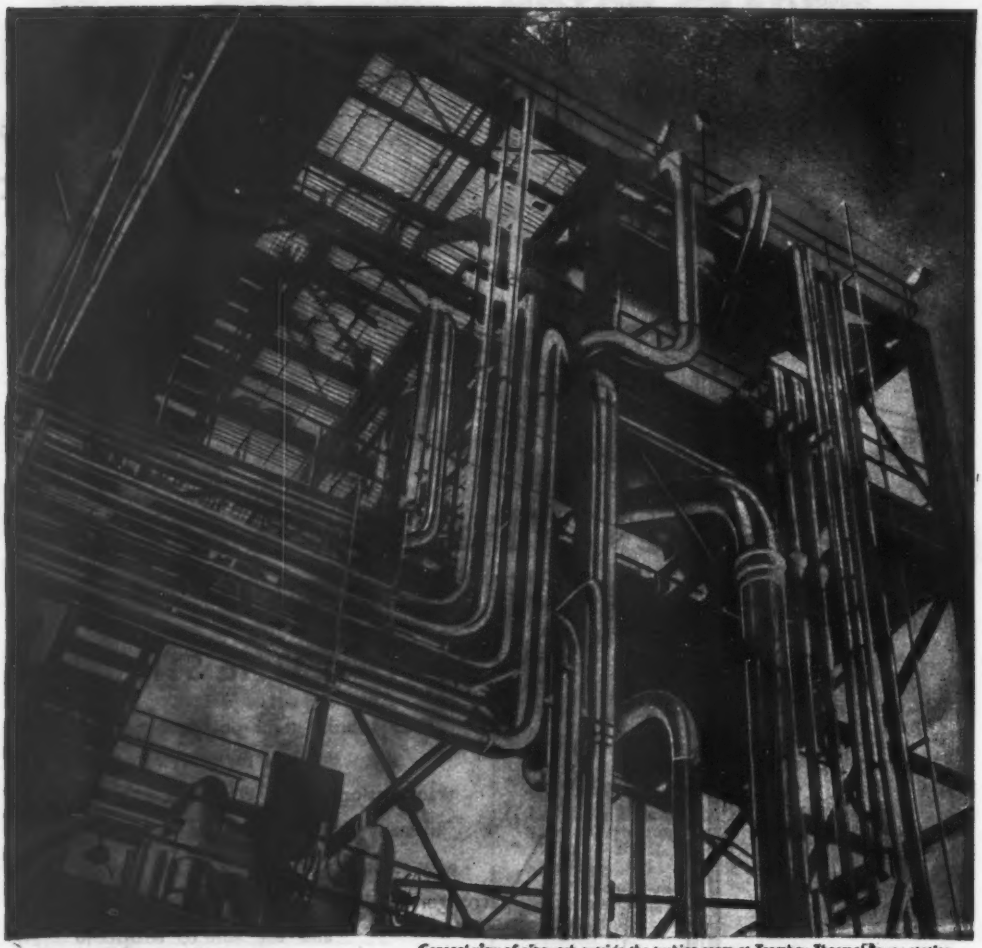

General view of pipework outside the turbine room at Trombay Thermal Power station

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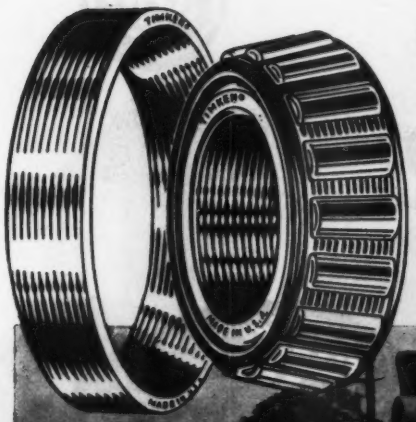

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Timken-bearing-equipped concrete mixers — such as the portable Jaegar Speedline Mixer — are a timesaver in construction work. Maximum dependability in performance is assured, because Timken tapered roller bearings take *both* radial and thrust loads with ease. The mixers run smoother, avoid work delays caused by time out for costly repairs and excessive maintenance.

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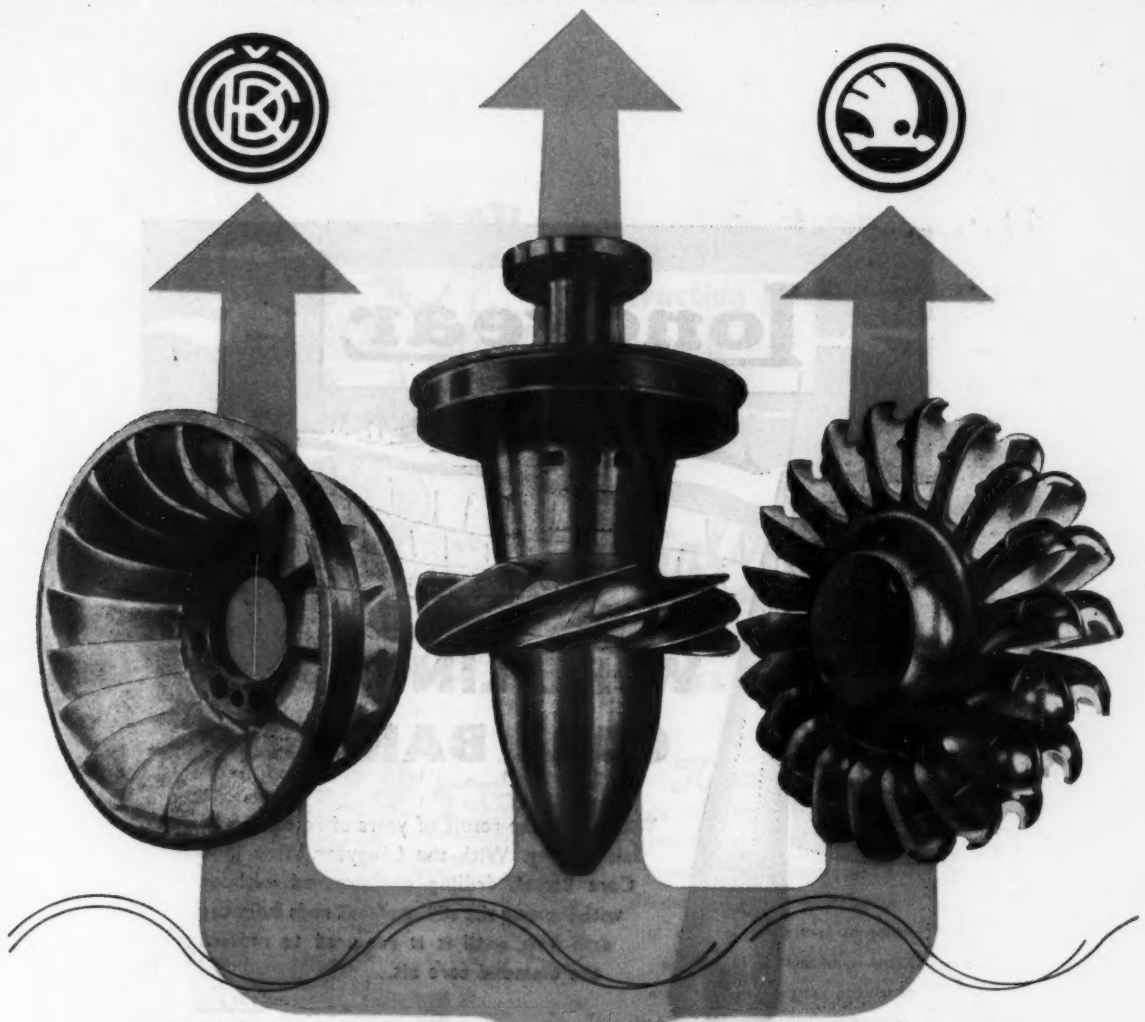

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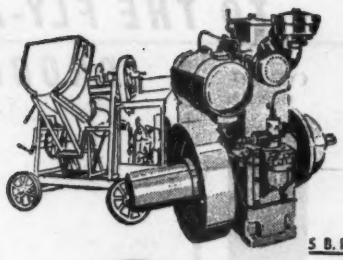

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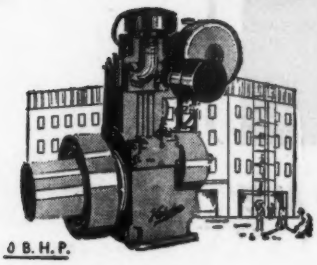

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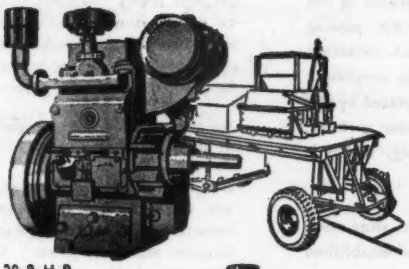

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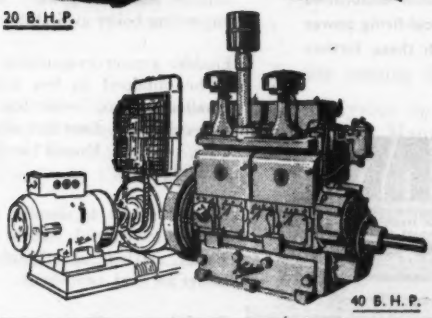

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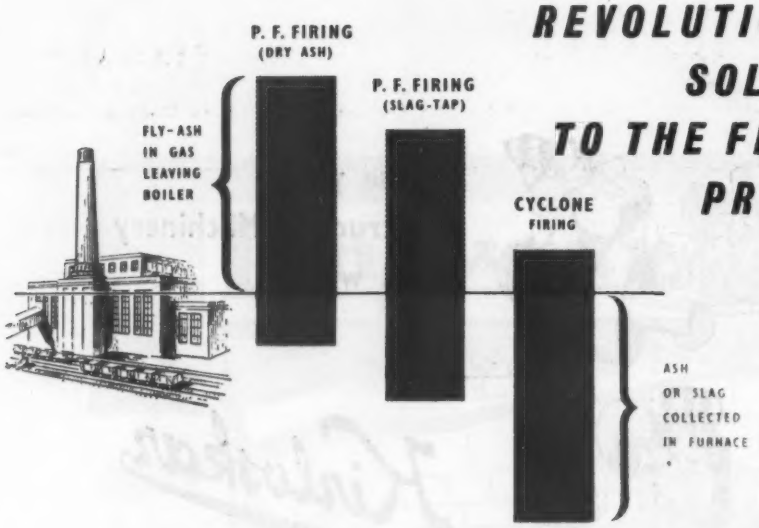

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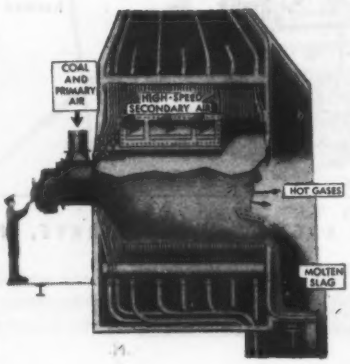

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Vol. VII — **JUNE 1957** — **No. 6**

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Kangsabati Project, West Bengal

By R. B. CHAKRAVARTY, M.I.E, M.Am.S.C.E.
Project and Superintending Engineer (Ex-Officio), Kangsabati Circle

Until there is any indication of a fall in the rate of growth of population it would be the duty of the present generatuon to move with relentless effort for producing more food. A substantial part of India's foreign exchange is consumed on account of foodgrain import every year and naturally industrial development is handicapped. The high prices of food grains in post-war years have induced peasants to cultivate wherever it is reasonably possible to raise any crop. Any substantial increase in the production would therefore, necessitate bringing under irrigation such lands which could not be cultivated so long for want of water. Increase in the production is also possible by increasing the yield of the lands already under cultivation with the help of artificial manuring, for the effective use of which assured water is essential. It is known that heavy manuring without sufficient water is even detrimental to the crop.

Speaking of West Bengal it may be said that Nature has provided this part of the country with good rainfall but full benefit of it cannot be derived in many of the years on account of its erratic distribution. The western part of the State consists of high undulating tracts of land with low lying valleys in between which drains the land quickly after a rainfall. It is this part of the State where irrigation is needed most. The Mayurakshi Project in a similar area in the district of Birbhum has changed the face of the district where cultivators are not to depend now on the rainfall, and are assured of a bumper crop every year.

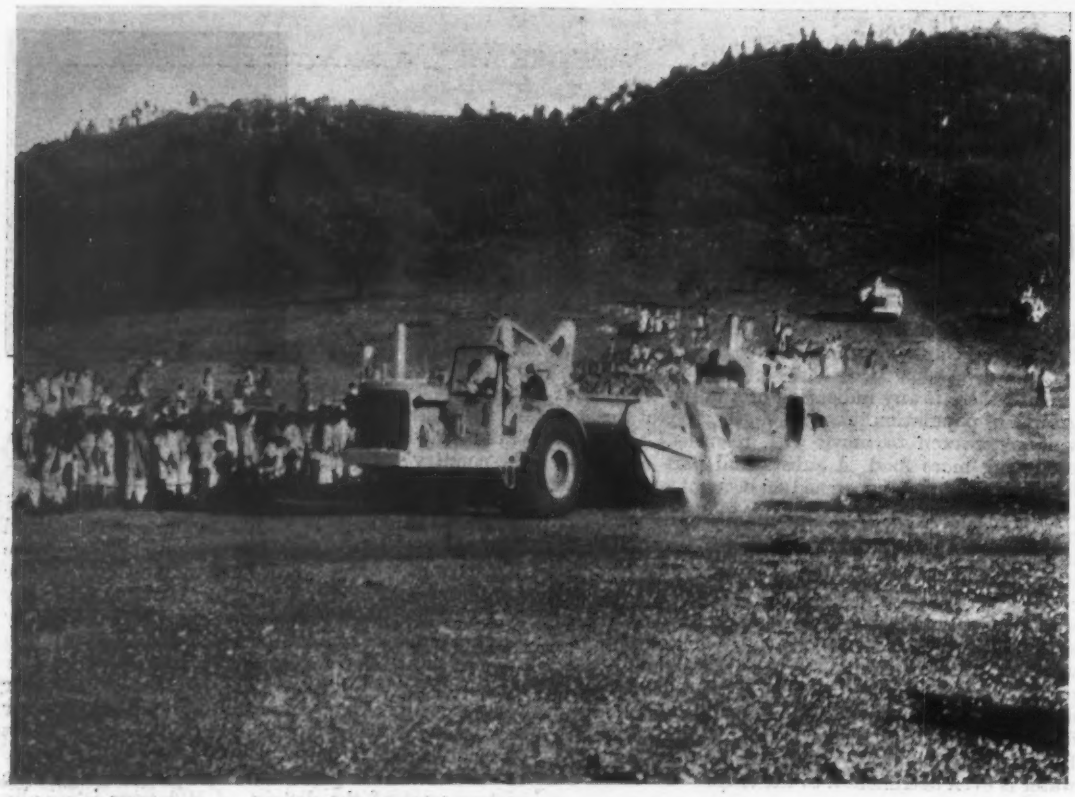
From the point of view of scarcity of water, the district of Bankura is even worse than the district of Birbhum and it is gratifying to note the Kangsabati Reservoir Project aiming at irrigating a major part of the district of Bankura along with the western part of the district of Midnapur, has found a place in the country's Second Five Year Plan.

1st Sod cutting by Shri Ajay K. Mukherji, 'Minister, Irrigation West Bengal.

The Kangsabati river commomly know as Kasai rises in the hills near Jhalda in the newly created district of Purulia, and after traversing through the districts of Bankura and Midnapur falls as river Haldi on the estuary. Like the Damodar, the Ajoy and the Mayuraskshi, this river also flows almost dry during the winter and summer months. The flow during a major part of the rainy season is also insufficient for irrigating more than a few thousand acres. The major part of its discharge flows in torrential floods after heavy precipitations in the catchment area. As a result of such floods, not only valuable water runs to waste but also the lower part of the valley consisting of the eastern part of the district of Midnapur is usually flooded. A reservoir is, therefore, essential and has accordingly been proposed in the scheme with a view to store the flood water for use at times of necessity. Apart from assuring water during the kharif months, which is the principal rice crop season, the storage may also be used during the dry months for rabi cultivation. Some water may even be reserved for pre-monsoon ploughing and seedling purposes, in case of late monsoon. With water assured the peasants may confidently invest more on manuring for a good return. The combined effect of manuring with irrigation is essential for optimum results.

The project as drawn up consists of the construction of a Dam across the Kangsabati valley near Khatra which is about 27 miles due South of Bankura, on the Kharagpur-Adra Section of the South Eastern Railway. The reservoir will cover an area of about 45 square miles and will be fed by the run off from a catchment area of about 1,400 square miles. The storage proposed for the reservoir is approximately one million acre-ft. 80% of which will be available for drawing into the canals. The proposal is to take off two canals at high level from the dam—one on each bank of the river. These main canals are to feed a number of branch canals which in their turn are to supply the requirements of the distributaries, covering the entire commanded are a, like the arterial system of the human body.

The dam will consists of a central surplus spillway to be made of cement concrete with long rolled fill earth dam sections on the two banks. The spillway openings will be controlled by radial type gates elec-



D W-21 Motor Scraper pushed by D-9 Tractors.

trically operated. The flood routing capacity of the spillway will be 375,000 cubic feet per second, which is considered to be the safe design discharge. The maximum height of the dam above the foundation will be about 170 ft. and its total length will be about 4 miles, the valley in the region being of a comparatively flat nature.

There will be high level sluices—one on each bank for supplying the canals. The feeder canal on the left bank carrying about 8,000 cubic feet per second will branch of into 2 Main Canals. One of these after crossing the river Silabati and other minor streams will be led towards Bankura for feeding the Vishnupur branch canal aligned towards Goghat in the district of Hooghly. The other will be taken towards Garbeta in the district of Midnapur with a branch towards the district town. The main canal on the right bank carrying about 3,000 cubic feet per second will similarly cross a number of hill streams and pass through Jhargram for irrigating the land upto the Railway Line from Kharagpur to Contai Road. The total area covered by the scheme will be about 2,000 square miles out of which a net 800,00 acres will be benefited. The scheme will also assure supply to the existing Midnapur Canals which draws its requirements from an anicut placed across the same river at Midnapur. The value of estimated extra additional annual yield of about 400,000 tons of food grains will be sufficient to cover the capital expenditure of 25 crores of rupees in a period of about 3 years only.

One very important aspect of the project is its flood routing provision.

The yield from the catchment area is limited and after meeting the requirements of irrigation there will not be sufficient water for generation of firm power. Arrangements are however, being made for the future possibility of generation of seasonal power which will be required for lift irrigation in the zone. The supply of domestic water will be another welcome benefit. This matter has all along been a serious problem in a greater part of the area. Pisciculture in the reservoir will add to the food supply and will give employment to fishermen.

The overall cost of the project is estimated at 25 crores of rupees. Against this, a sum of Rs. 5 crores has been allotted during the 2nd plan period to give a start. Attempts are, however, being made to increase the allotment so that a faster programme may be possible.

Quite a large number of machinery will have to be used in unavoidable cases. Even then the greater part of the work will have to be done by manual labour, which will provide employment to the poorer people of the area who in most years live on Test Relief Works undertaken by the Government.

An unfortunate aspect of most reservoir schemes is the displacement of people from the reservoir area. Attempts are however being made in this Project to reduce this number as far as practicable by a little adjustment of the site. The displaced persons will, of course, be much better off, if they are resettled in some of the new tracts of land coming under irrigation as a result of this scheme.

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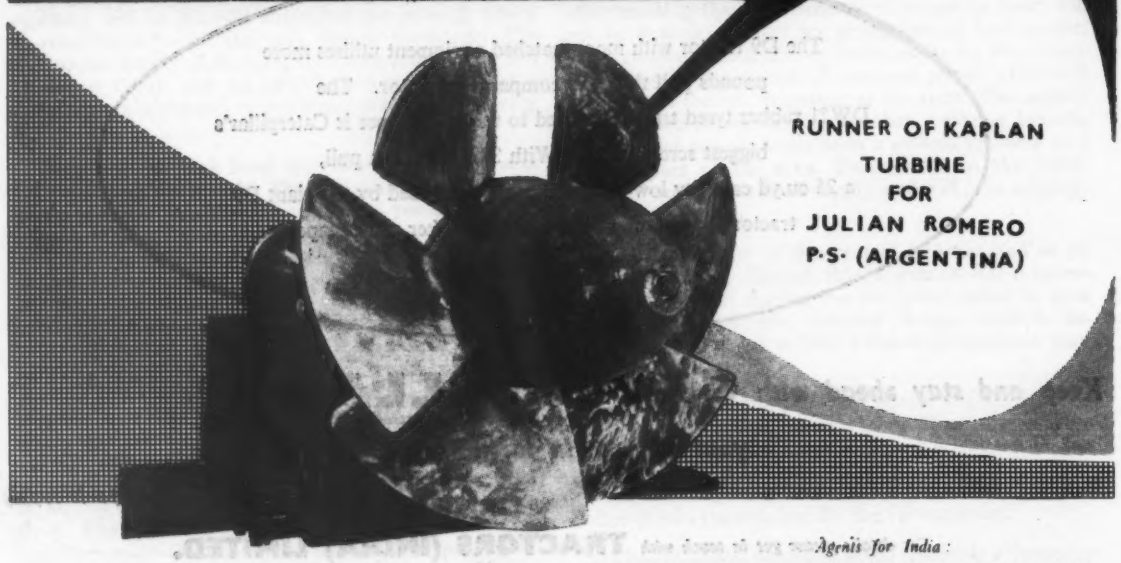

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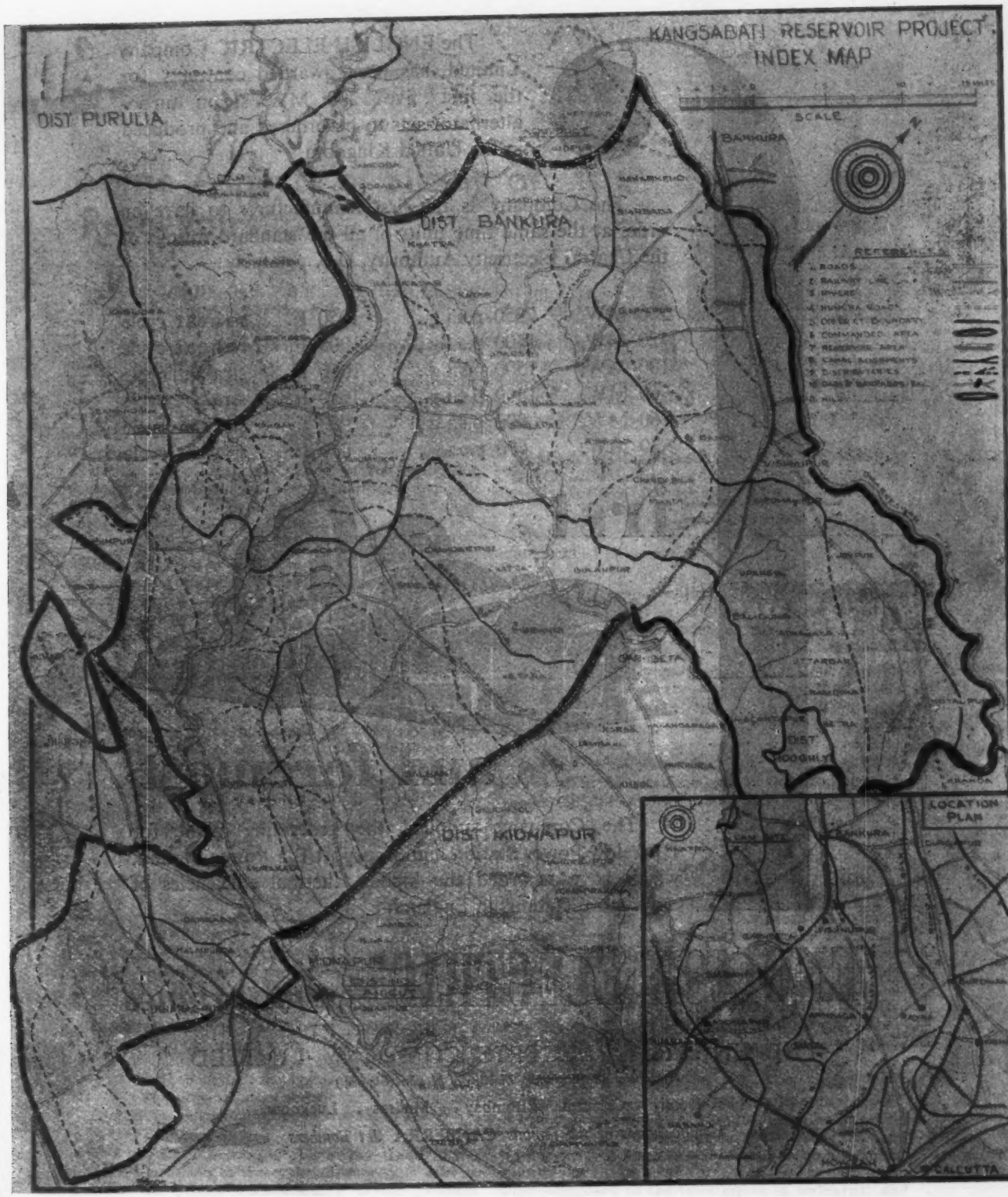
KANGSABATI RESERVOIR PROJECT
INDEX MAP
SCALE
DIST PURULIA
DIST BANKURA
DIST MIDNAPUR
BANKURA
LOCATION PLAN
CALCUTTA

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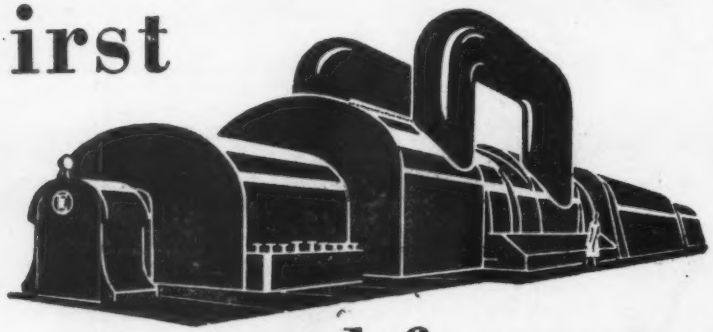
60 MW,	900 p.s.i.g.,	900° F.	straight cycle
30 MW,	600 p.s.i.g.,	850° F.	straight cycle

first



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Some Aspects of Silting of Reservoirs

By R. J. GARDE, B.Sc., B.E., M.S (Irrig. Eng.) (Colorado), Jr.M.A.S.C.E.,
A and M College, Colorado, U S.A.

The recently-developed branch of engineering known as sediment engineering is based on the fact that flowing water has a variable capacity to carry sediment with it. Thus, as the clear water flows over the watershed, it picks up material and if the carrying capacity of the flow for the sediment is not satisfied, the process of picking up more sediment goes on even when the water enters the river channel. Once this capacity is satisfied, the flow is saturated and will not pick up more sediment from the bed or the sides of the channel.

When the velocity of flow in the channel is reduced as a result of entrance into a large pool created by construction of a dam across the channel, the transporting capacity of the flow for sediment is also greatly reduced. Hence, excess of sediment over and above the transporting capacity of flow at any place will be deposited on the bottom of the reservoir. This is the principal cause of silting of reservoirs.

Therefore, any method employed in studying the problem of silting of reservoirs should necessarily be based on the amount of sediment that is being brought into the reservoir by the particular stream.

Variables entering the problem

There are several variables which influence silting of resorvoirs in direct or indirect manner. These variables are generally classified under the following heads :

Flow characteristics
Sediment characteristics
Fluid characteristics
Reservoir characteristics
Watershed Characteristics

The effect of these variables is usually one or a a combination of the following :

(*a*) To prevent or tend to change the sediment load carried by the stream.
(*b*) Cause deposition of sediment.
(*c*) Remove sediment out of the reservoir.

It is not the intention of this article to go into a detailed discussion of these variables or their effects, but for the proper understanding of the problem they are listed below :

Flow characteristics : Maximum, minimum and average discharge of the stream at the dam site ; frequency of the discharge of various flow magnitudes ; amount of water spilled over the dam ; sediment concentration of the flow entering the reservoir.

Sediment characteristics : Size and variability of size of the sediment load carried by the stream ; specific gravity of the sediment.

Fluid characteristics : Specific weight, viscosity and chemical properties of water.

Reservoir characteristics : Reservoir capacity ; size and shape of reservoir ; sluices and other openings ; nature of reservoir operation.

Watershed characteristics : Average slope of watershed ; geology ; vegetal cover ; intensity, duration and distribution of rainfall ; mean air temperature and its variation.

It must be admitted that the present day knowledge of this branch of engineering is not adequate to handle all the above variables in a quantitative manner.

Sediment balance

The amount of sediment, Sd, that will be deposited in the reservoir during any given period will be equal to the difference between the amount of sediment coming into the reservoir during that time, S_i, and the total amount of sediment going out of the reservoir through sluices, head works and over the spillways, S_o, and the change in the amount of sediment held in suspension in stored water during the same time interval, S_s. Or in equation form one can write:

$$S_d = S_i - (S_o + S_s)$$

Therefore, for the systematic evaluation of the amount of sediment that will be deposited in the reservoir, one must know the amount of sediment coming in and going out of the resorvoir. It can be conveniently assumed that the change of amount of the sediment, held in suspension in the stored water, is very small when compared to the total inflow of sediment, and therefore, as a first approximation it can be neglected.

Definitions

Before going further into discussion of the subject, it seems important to define certain terms which will be used frequently.

The Subcommittee on Sediment Terminology of the American Geophysical Union [14] has recommended the following definitions for various divisions of material being transported by the stream :

(*a*) According to the type of movement :

Contact Load is the material rolled or slid along the bed in substantially continuous contact with bed.

Saltation Load is the material bouncing along the bed, or moved directly or indirectly, by the impact of bouncing particles.

Suspended Load is the material moving in suspension in a fluid, being kept up by the upward components of the turbulent currents or by colloidal suspension.

(*b*) According to source of material :

Bed Material Load is part of the sediment load of a stream which is composed of particle sizes found in appreciable quantities in the shifting portions of the stream bed.

Wash Load is that part of the sediment load of a stream which is composed of particle sizes smaller than those found in the shifting portions of the stream bed.

Depending on the method of measurement one can also classify the sediment load as measured and unmeasured load.

Therefore, the total sediment load carried by a stream can be expressed as either

Bed material load + Wash load *or*
Suspended load + Saltation load + Contact load *or*
Measured load + Unmeasured Load.

Sediment inflow

For the present discussion the total sediment load carried by the stream is taken as the sum of measured load and unmeasured load. Measured load usually can be determined to a reasonable degree of accuracy, by using devices such as various suspended load samplers. Although the samplers for suspended load have been developed to a rather high degree of refinement, there is no completely satisfactory method to find the quantity of unmeasured load.

A large part of the unmeasured load which is bedload (usually considered to be the sum of contact load and saltation load) can be computed by using one of the equations developed by Meyer-Peter, Straub, Kalinske, or Einstein. But, in spite of the fact that some of these formulae have great merit, they are only occasionally used in the field conditions at present time mainly because :

(*a*) More verification is needed to prove the reliability in applying those to field conditions, and

(*b*) Frequently sufficient field data are not available to apply those formulae to field conditions.

When suspended load samples are used, another method of estimating the unmeasured load is by assuming that it is a certain percent of the total measured suspended load being transported.[8] This percent will naturally depend on various factors and will vary from nearly zero to one hundred percent or more. In short, some of the major factors influencing this percent will be :

(*a*) Size of the bed material

(*b*) Slope of the stream or the average velocity.

(*c*) Nature of the channel including the depth, the size, the shape and the roughness of banks and and bed of the channel.

(*d*) Properties of fluid such as temperature.

A stream channel having intense turbulence will tend to keep more sediment in suspension and therefore the percentage of unmeasured load will be smaller. Similar will be the case for large flows. If the difference between the sizes of measured load and the unmeasured load is small, the percent mentioned above will be greater than in the case where the difference in sizes in larger. In general, the smaller the actual concentration of measured load, the greater will be the percent of the unmeasured load.

Lane and Borland [8] have correctly pointed out that the magnitude of unmeasured load percent will also depend on the source of sediment. Sediment produced by sheet erosion will usually be fine and therefore will tend to have smaller unmeasured load. Gully erosion and bank cutting will usually produce large size material and hence will tend to have a large percent of unmeasured load.

For the convenience of the reader, Table 1 see next page gives Maddock's classification for determining this percentage. This is by far the best available information for the estimation of unmeasured load without sampling the material which is transported near the bottom of the channel.

The order to relate total sediment transport rate to measured suspended sediment transport rate, Sadar[12] studied the sediment sampling efficiency of suspended sediment sampler using fine sand. It is interesting to note that the percentages, given by Maddock in Table 1 for the case of sand, are within the range of percentages obtained by Sadar

Method of computing sediment inflow rate

The time available between proposal of a project and the final approval varies within great limits. Therefore, realising that long term records of sediment discharges and sometimes even the records of water discharges are not many times available in Asian countries, a method based on less data should be utilized to compute the sediment inflow rate or total inflow during a given period. Such a method is described below.

TABLE 1

Maddock's classification to determine unmeasured load

Conc. of measured susp. sediment. ppm	*Type of material forming the channel*	*Texture of the suspended material*	*Unmeasured load per-cent*
Less than 1,000	sand	similar to bed material	25 to 150
Less than 1,000	gravel, rock or consolidated clay	small amount of sand	5 to 12
1,000 to 7,500	sand	similar to bed materi l	10 to 35
1,000 to 7,500	gravel, rock or consolidated clay	25 percent sand or clay	5 to 12
Over 7,500	sand	similar to bed material	5 to 15
Over 7,500	gravel, rock or consolidated clay	25 percent sand or less	2 to 8

From whatever data available from the records of the past few years of suspended load carried by the stream, and knowing the sizes of the measured suspended load and the unmeasured load, an estimation can be made of total sediment load transported corresponding to each measurement of the suspended load. For this estimation Lane and Borland's method[8] described above can be used, in case no bed load data are available. Knowing the water discharges at times corresponding to the times for which measured suspended load data are available, a plot can be made of Q_w (Water discharge per unit time) against Q_s (total sediment discharge per unit time). Such a plot for a particular river is shown in Fig. 1 at the end of article. An average curve can be drawn through the points. It will usually be convenient to use log-log paper for such a plot, and when such a paper is used, care should be taken in drawing an average line through the points. The following procedure is suggested for drawing such an average curve. The range of the abscissa can be divided into 12 to 15 intervals or more according to convenience. Ordinates of all the points lying in a given interval then may be added and their arithmetic mean computed. In a similar way, the abscissae of all the points lying in the same interval may be summed and their arithmetic mean computed. The process should be repeated for all the intervals in which the range of the abscissa was divided. The average curve should, as nearly as possible, pass through the points whose coordinates are the arithmetic mean abscissae and ordinates for each interval as computed above.

Another plot should also be made with percent of time as the ordinate and water discharge Q_w, which was equalled or exceeded for that percent of time, as the abscissa. For preparing such a plot, the available discharge data should be arranged in descending order of magnitude and then percent of the time for which the discharge was equal to or greater than a given amount be determined. Such a plot is shown in Fig. 2.

For the third plot (see Fig. 3) the ordinate is percent of time and the abscissa is the total sedmiment discharge Q_s. Using Fig. 2, water discharge Q_{wi} for a certain percent of time T_i is found. For this dissharge Q_{wi}, the total sediment discharge Q_s is obtained by using Fig. 1. This gives the coordinates of one point on Fig. 3. Repeating the same procedure for different percents of time Fig. 3 can be completed. If area under the curve in Fig. 3 is found and when it is divided by the total ordinate, this will give the average sediment discharge Q_s. If this average sediment discharge Q_s flows for 100 percent of the time, it will give the same amount of total sediment discharge as will be given when the rate of flow of sediment is as given by the curve on Fig. 3. This sediment inflow rate should be used to compute the total amount of sediment that will come into the reservoir in a given time.

The degree of accuracy, in finding the total inflow of sediment according to the above method, will naturally depend on the accuracy of data used and also on the length of time for which the data are available. If the data available are for the years which can be called normal as far as the water discharge is concerned, it will give a closer approximation than when the data used cover predominantly droughts or flood conditions. If the data are available for longer periods, such abnormal conditions of floods or drought will be smoothened to a certain extent.

If the discharge or sediment conditions of the stream vary to very large extent during different seasons of the year, as is the case with many rivers in India, it will be necessary to use the above method for each season. Then the rates obtained for each season will be added to obtain the annual sediment inflow rate. This will give better accuracy than when the sediment rating curve is prepared for the whole period.

Sediment outflow

The amount of sediment going out of the reservoir

will depend on many factors, such as size of sediment in suspension, ratio of storage capacity of the reservoir to annual runoff at the site, quantity and quality of the water going out through the head works or the sluices and over the spillway, and location of outlet works.

The action of reservoirs can be compared to the action of sedimentation tanks or the settling tanks in sewage treatment works ; but in the case of reservoirs the problem is more difficult and complicated because inflow rate and depth of water in the reservoir changes through a wider range than in settling tanks.

Retention time can be defined as the time that water requires to pass through reservoir. For a particular region, if the drainage area of the basin is taken as an approximate index of annual runoff, the storage capacity of the reservoir per square mile of the drainage area will indicate very roughly the relative retention time. A plot of storage capacity per square mile of drainage area against sediment trapped in the reservoir expressed as percent of total inflow of sediment is prepared by Gottschalk[5] for some reservoirs in the United States. Gottschalk's plot is shown in Fig. 4. This figure shows that the trap efficiency of a reservoir increases with the increase in storage capacity per square mile. It will be realized that, for reservoirs with large storage capacities per square mile of drainage area, the trap efficiency will be about 100 percent for the first few years and as the reservoir fills with the sediment, the trap efficiency will decrease.

Brune[2] analysed the records of 44 different reservoirs in the United States and found that capacity to inflow ratio gives better correlation with the trap efficiency than the capacity to watershed ratio as suggested by Gottschalk[5]. The reason is that, capacity to watershed ratio must be used within definite hydrologic regions, and not as an index of comparison over the country as a whole, for, with the same ratio of capacity to watershed area the trap efficiency will increase as the runoff per unit area decreases. Fig. 5 shows Brune's plot. In the absence of any other data, this plot can be used as a guide in the design problems.

Churchill[5] after analysing the data from TVA reservoirs, came to the conclusion that along with the retention time, the transit velocity—velocity with which the water flows in the reservoir—is also very important in determining the trap efficiency. If the water held in the reservoir is moving fairly rapidly in the reservoir, very little sedimentation will occur even though the retention time may be long. He defined a parameter "sedimentation index" which is a ratio of period of retention to mean transit velocity. A plot was made for the computed values of the sedimentation index for successive periods of time (three month periods were used in this particular case) and the percent of incoming silt that passed through the reservoir. Churchill's plot is shown in Fig. 6. As the reservoir becomes filled with the sediment, the period of retention will decrease and the mean transit velocity will increase. Therefore, sedimentation index will decrease and greater percent of incoming silt load is passed through the reservoir.

If a large percent of the sediment in the stream is moving in the form of density currents, then the concept of "mean transit velocity" introduced by Churchill is questionable. In such a case, the velocity of density currents may be very different from the mean transit velocity.

It must be added that sufficient information is not available to determine with accuracy the trap efficiency for a particular reservoir. For preliminary work, either the plot developed by Brune (see Fig. 5) may be used or if the storage capacity is very great compared to annual inflow and the size of the suspended sediment is medium or large, the trap efficiency may be taken as 100 percent.

Deposition of Sediment

The location where the sediment will be deposited in the reservoir is governed by many factors, important ones being the size and gradation of the sediment and size and shape of the reservoir. Considering the flow in the reservoir as two dismensional, Lane[7] has discussed in detail the manner in which sediment is deposited in the reservoirs. Lane divided these deposits into top-set beds, forest beds, bottom-set beds and density current deposits. See Fig. 7.

Top-set beds are usually composed of large size sediment. They extend upstream upto the point where the backwater curve extends upstream from the reservoir. Since such a point is usually far above the reservoir level, it will not materially affect the capacity of reservoir. Of course it will cause other troubles such as raising stream bed level in the upstream. Fore-set beds and bottom-set beds are composed of less coarse and finer material respectively. Bottom-set beds being composed of material in silt and clay range, a large part of such material will be carried down and discharged over the dam if the retention period is small.

It will not be out of place here to define and describe density currents. Density currents (which are more correctly known as gravity currents) are defined as gravity flow of fluid through, under or over a fluid of approximately equal specific weight. Depending on the cause of formation, the density currents are classified as follows[9] :

(*a*) Density currents with movement due to the suspension of sediment in flowing water.
(*b*) Density currents caused by dissolved material in water.
(*c*) Density currents with movement due to difference in specific weight set up by the difference in temperature.

Hydraulic engineers are mainly concerned with class "a" type of density currents which are known as "turbidity currents" or "underflow" type of density currents. Formation of the turbidity currents and the position at which they travel are complex phenomena. Formation of turbidity currents is usually predominant under following conditions :

(*a*) Fine sediment
(*b*) High concentrations of sediment
(*c*) Steep stream slopes
(*d*) Large depths of water

There is a considerable controversy as to whether it is possible to flush the turbidity currents, through

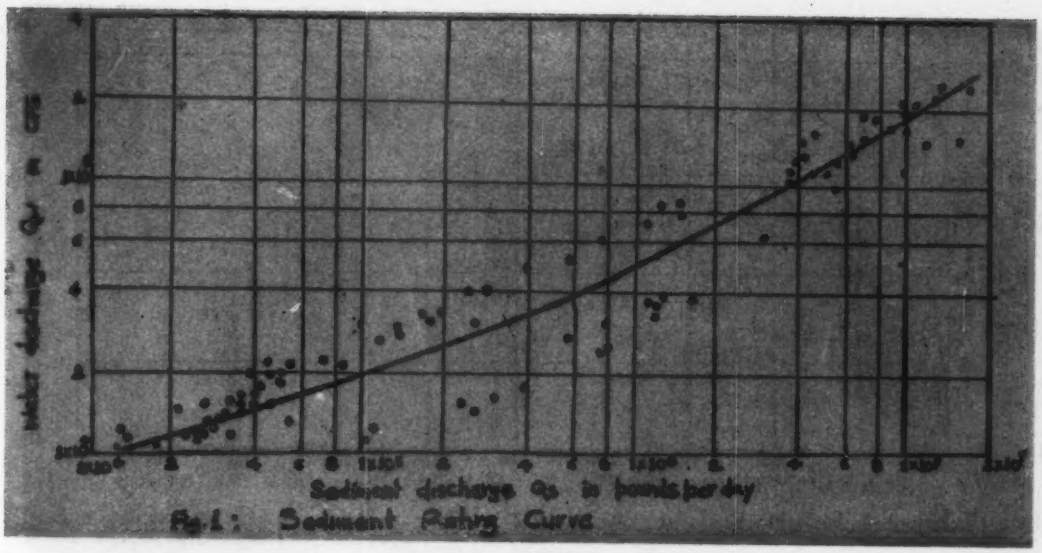


Fig-1: Sediment Rating Curve

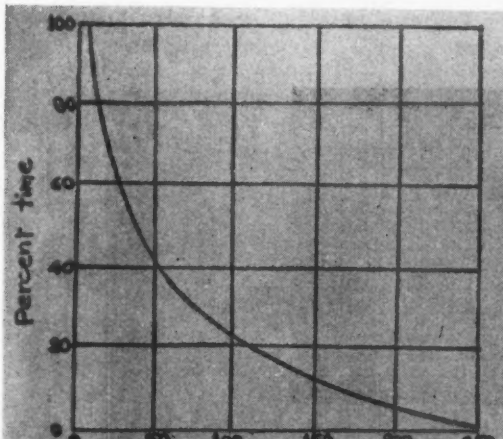


Fig-2 : Water Discharge Distribution Curve.

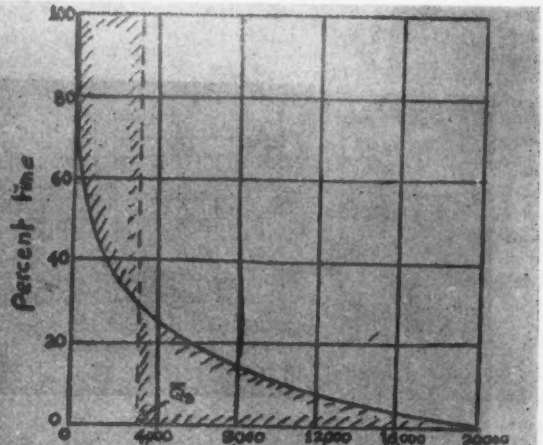


Fig.3 : Sediment-Discharge Distribution Curve.

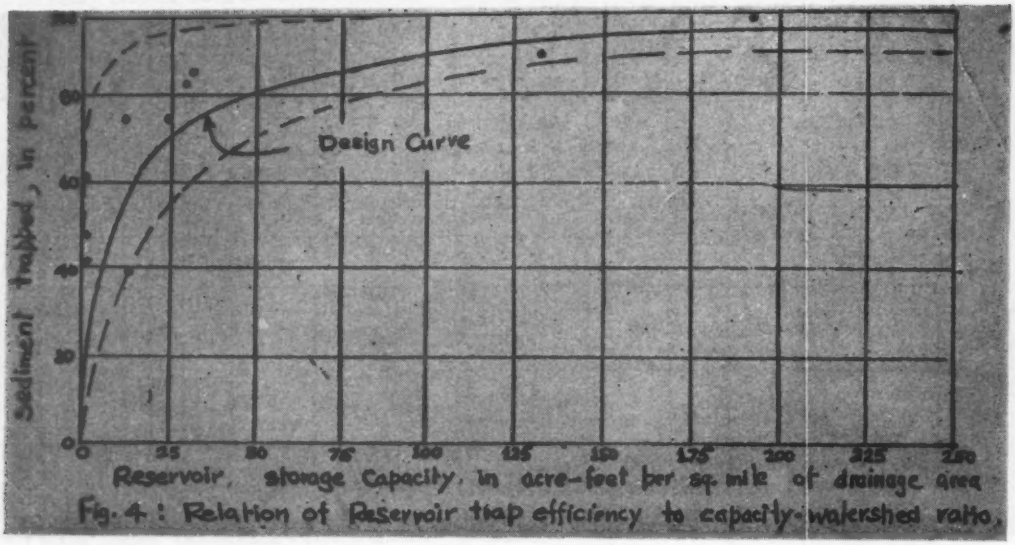


Fig. 4 : Relation of Reservoir trap efficiency to capacity-watershed ratio.

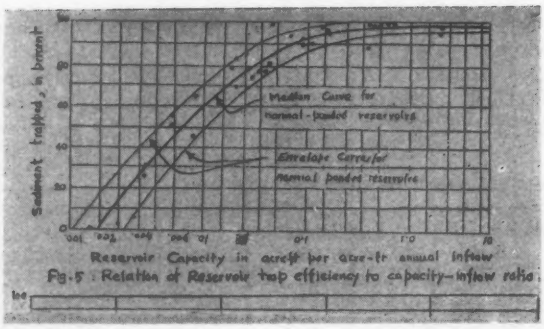

Sediment trapped, in percent
Median Curve for normal-pooled reservoirs
Envelope Curve for normal pooled reservoirs
Reservoir Capacity in acre-ft per acre-ft annual inflow

Fig. 5 : Relation of Reservoir trap efficiency to capacity-inflow ratio.

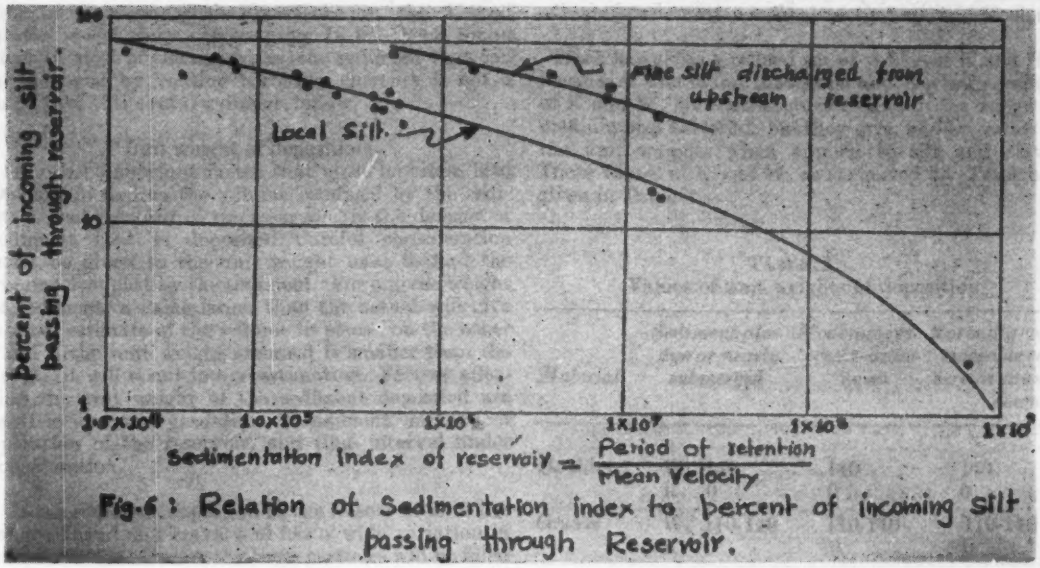


Fig.6 : Relation of Sedimentation Index to percent of incoming silt passing through Reservoir.

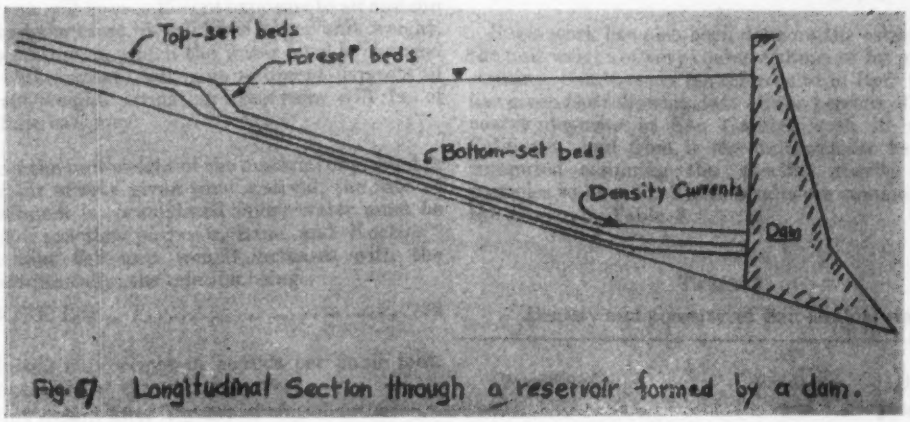
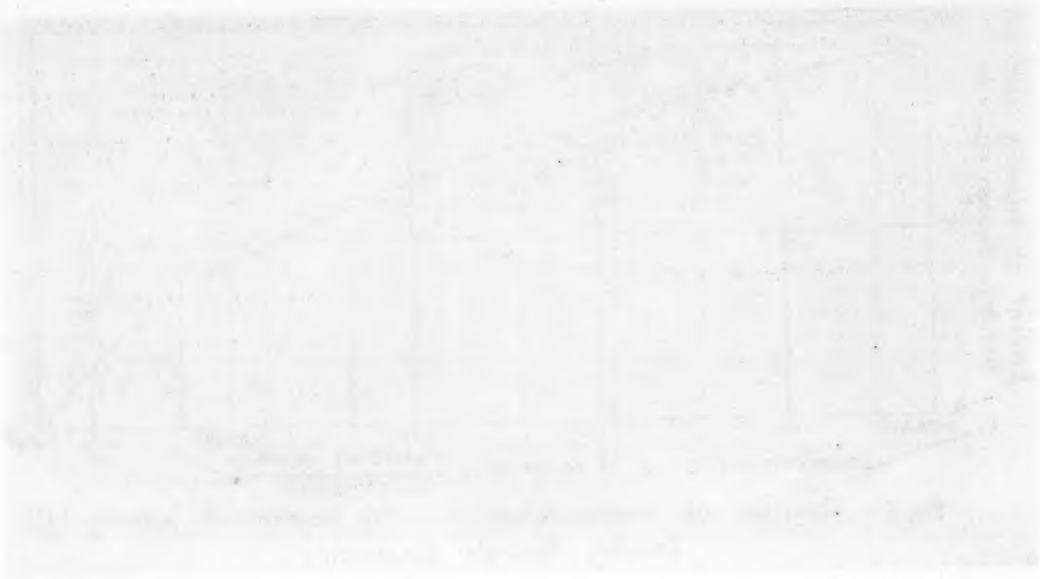


Fig. 7 Longitudinal Section through a reservoir formed by a dam.



the sluices of the dam, in order to decrease the deposits in reservoirs. The experience in the United States is not very encouraging. It has been found that, in most of the reservoirs, the sediment that can be removed by venting turbidity currents is not a large part of the total sediment inflow.

Unit weight of deposition

Another important factor that must be taken into account in finding the volume occupied by the sediment load retained in the reservoir, is the density of sediment that is deposited. Careful consideration must be given to the unit weight used to find the volume occupied by the sediment. For a given weight of sediment, a value larger than the actual will give a lower estimate of the volume in place ; on the other hand if the unit weight assumed is smaller than the actual, it will result in overestimation. Factors affecting the unit weight of the sediment deposited are particle size and gradation of sediment, method of operation of the reservoir, and time interval under consideration.

If the sediment deposited in the reservoir is in the range of sand and gravel and has a wide variation in size, the voids between the large particles will be filled by the smaller particles. Therefore, the unit weight will be relatively large in the beginning. It is also clear that there will be relatively small consolidation as the time passes, and hence there will not be much variation in unit weight with increase in time. Silt and clay will have smaller initial unit weight but it will increase to a large extent as the time passes and consolidation takes place.

Another factor is the method of reservoir operation. If the reservoir acts as a detention basin which is filled during the flood periods and is empty during the rest of the time, the sediment settled on the bottom of the reservoir will have sufficient exposure to air and sun to dry, and therefore, it will have larger unit weight. Those reservoirs, in which the water level is changed to very little extent, will have sediment deposits of lower unit weight. Irrigation reservoirs will be of intermediate category.

To know the unit weight of the material deposited in the reservoir after a given time interval, the rate at which sediment is consolidated under water must be known. For practical purposes, Lane and Koelzer [10] assumed that the unit weight increases with the time logarithmically, the relation being

$$W = W_o + K \log_{10} T \quad \ldots\ldots 2$$

where

W_o = Initial unit weight in pounds per cubic foot, considered at the end of one year.

W = Unit weight after T years of consolidation

K = A constant depending on the nature of reservoir operation and the size of sediment deposited on the bottom.

It can be seen easily that if the sediment deposited in the reservoir is in the range of sand and gravel, K will be close to zero because the material can be consolidated only very little. Therefore, the unit weight will be reasonably constant with respect to time. Also, if the sediment is always under water, K will have a larger value than in the case when the sediment is occasionally exposed to the sun. Values of K and W_o for different size materials and for different conditions of reservoir operation were given by Lane and Koelzer.

Trask has given a refined set of values of K and W_o because it was found that Lane and Koelzer's values of K and W_o give satisfactory results in the range of medium size material, but they give higher value of the unit weights when applied to silt and clays. These values of K and W_o as suggested by Trask are given in Table 2.

TABLE 2.
Values of unit weights of deposition

Material	*Sediment always or nearly submerged*	*Moderate reservoir drawdown*	*Normally considerable reservoir drawdown*
Boulder	W_o 140	140	140
	K 0	0	0
Gravel	W_o 110-140	110-140	110-140
	K 0	0	0
Coarse sand	W_o 93-110	93-110	93-110
	K 0	0	0
Sand	W_o 88	88	88
	K 0	0	0
Silt	W_o 67	76*	81*
	K 5.7	2.7	1.0
Clay	W_o 13	—	—
	K 16.0	10.7	6.0

*Estimated
(Table 2 is taken from reference 13 in Bibliography)

Some work has also been done on the estimation of the unit weight of very coarse sediments by mountain streams. Sonderegger (as referred to in Ref. 10, p.29) has given the following data on the percent of voids of coarse deposits in San Gabriel wash in southern California, and from it the unit weights have been computed assuming the specific gravity of the particles to be 2.65. Those results are summarized for the reader in Table 3.

TABLE 3.
Density and porosity of San Grabiel wash

Classification	*Voids per-cent*	*Density pounds/c.ft.*
Boulders, gravel sand	12	146
Coarse gravel and sand	17	137
Medium gravel and sand	20	132
Fine gravel and sand	28	119

According to Miller [11], the average unit weight, W_{av} after T years of compaction is given by :

$$W_{av} = W_o + 0.434\ K \left[\frac{T}{T-1} (\log_e T) - 1 \right] \quad \ldots 3$$

If the sediment deposited in the reservoir belongs to different classes such as gravel, sand, silt, then one must know their percentages to compute the average values of K and W_o. Thus, if in a particular reservoir, the deposited material contains 20 percent clay, 40 percent silt and 40 percent sand, and if the reservoir has moderate draw down, then by using table 2, one gets :

$$W_o = (10 \times 0.20 + 76 \times 0.40 + 88 \times 0.40)$$
$$= 67.6 \text{ lbs/cft. (clay is assumed to have } W_o = 10)$$

Similarly

$$K = (10.7 \times 0.20 + 2.7 \times 0.40 + 0.0 \times 0.40)$$
$$= 3.22$$

These values should be used in the above equations to find the necessary unit weight.

The answers obtained by using the above equations are found not to vary more than 5 percent for more extreme cases [11]. Taking into consideration other possible sources of inaccuracy, it is believed that this accuracy is sufficient for the use in sediment volume computations.

Closing remarks

Thus, knowing the amount of sediment that will be stored in the reservoir every year, and knowing the average density, one can estimate what percent volume of the total storage capacity will be occupied by the sediment; or in other words one can estimate the probable period during which the capacity of the reservoir will be reduced by a certain percentage.

This is a short account of the method that can be used to study silting of reservoirs. Higher accuracy can be obtained if more reliable and long term records of the basic data are available : similarly, the method can be refined to a very large extent depending on the time and funds available.

Such a method, as described above, is preferable to any method which is based on assuming immediately the total volume of sediment coming into the reservoir every year. The reason is that, in the method described above, as the whole problem is subdivided into different logical steps, the engineer knows what assumptions he has to make to go through the whole process. In making these assumptions there is ample opportunity for the engineer to use many kinds of information —qualitative as well as quantitative—that is available. Therefore, there is greater chance of getting a more rational estimate of the volume that will be occupied by the silt coming into the reservoir during a given time.

Acknowledgement

The writer wishes to express his gratitude to E.W. Lane and M.L. Albertson, both professors of Civil Engineering at Colorado Agricultural and Mechanical College, Fort Collins, Colorado, for their useful suggestions in preparing this article.

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Flood Forecasting in Damodar Valley Area by Statistical Method: A preliminary investigation

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The Damodar Valley area, comprising of Damodar and Barakar catchments, will have four reservoirs in the first stage of development for providing flood-control, supply of water for irrigation and power production. Of these, the two principal ones, Maithon and Panchet Hill, are still under construction. As these reservoirs are located near the area where floods generally occur and are also contiguous to the areas to be irrigated, the reservoirs will have to bear the main brunt of regulating the flow of Barakar and Damodar rivers for the multi-purpose projects mentioned above. In order to achieve an ideal flood-control operation of the reservoir, it is not only necessary to have a forecast of inflows or change in water level over a period of time sufficient to fill up and empty the reservoir but a prediction is also necessary for the change in the water level in the stream below the dam because the water that can be let-off from the reservoir will naturally depend on the condition of the downstream. For instance, if the downstream is full or nearly full, letting off further quantity of water will cause flood in the downstream.

For developing the technique for such river forecasting several years' hydrometeorological data viz. run-off volume, river-level or discharge rates of the reservoir and of the downstreams, and rainfall amounts are required. Of these, forecasting of rainfall over the D.V. area plays by far the most important role, particularly during the monsoon season. As the construction of all the reservoirs is not yet complete, it will take some more years before the required data for the reservoirs become available and a detailed study in the line of Sherman,[1] Zoch[2]; Linsley and Ackermann[3]; Light and Kohler[4] is not possible at this stage. In the present study an atttempt has therefore been made to investigate how far the mutual relationship amongst the various hydrometeorological factors throw light on the estimation of floods in the D.V. area. For this purpose only two years' (1951 and 1952) data from June to 20th October have been considered sufficient. The choice of these two particular years is mainly because of the fact that the construction work of the dams at Maithon and Panchet might not have affected the hydrological observations considered, the work being almost at the infant stage in these years.

Rainfall and River Level

To establish the best relationship between river level and rainfall, average rainfall from various groups of raingauge stations in addition to the average rainfall over the catchment may be correlated with the river level for which forecast is required. In the case of Maithon, such a correlation analysis reveals that daily average rainfall based on the representative raingauge station in the Barakar catchment as selected by Majumdar and Gangopadhyay[5] is comparatively more highly correlated with the river level at 18.00 hrs.; while in case of Damodar Bridge which is affected by both Damodar and Barakar rivers, the raingauge stations selected are those situated on or near these two rivers. These raingauge stations are shown in diagram I.

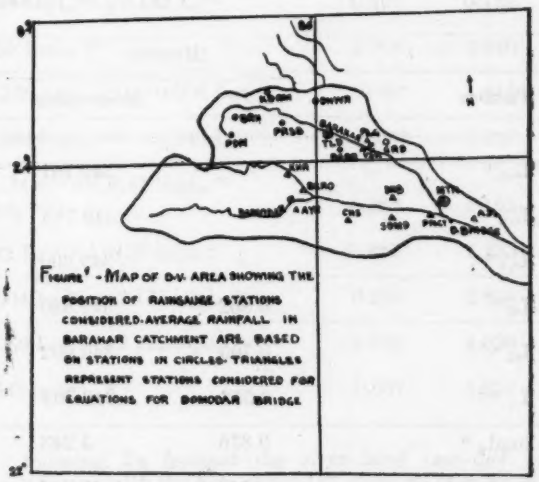


FIGURE 1 - MAP OF D-V AREA SHOWING THE POSITION OF RAINGAUGE STATIONS CONSIDERED. AVERAGE RAINFALL IN BARAKAR CATCHMENT ARE BASED ON STATIONS IN CIRCLES. TRIANGLES REPRESENT STATIONS CONSIDERED FOR EQUATIONS FOR DOMODAR BRIDGE

Average rainfall indirectly accounts for the surface run-off to a great extent and as such the above correlation coefficients are found to be sufficiently, though not extremely, high. Obviously a linear relationship between the river level and the average rainfall may be quite useful for prediction purposes. From almost similar considerations Paramanik and Rao[6] also obtained a few forecast formulae for discharge at Rhondia, but their results are based on mean discharge data instead of those recorded at fixed hour.

Denoting the river level recorded at 18.00 hrs. I.S.T. on say, n^{th} day by $L_{18}^{(n)}$ and the average rainfall recorded during twentyfour hours ending 08.30 hrs. on n^{th} day and $(n-1)^{th}$ day by $r^{(n)}$ and

$r^{(n-1)}$ respectively, following linear regression equations have been obtained by least square method. These are based on 284 observations during June to October spread over two years considered.

Maithon

Simple regression : $L_{18}^{(n)} = 348.893 + 3.160\ r^{(n)}$ (1)

$$V(L_{18})^{(n)} = .00842 + .05089(r^{(n)} - .02747)^2$$

$$R = 0.642 \quad (2)$$

Multiple regression :

$$L_{18}^{(n)} = 348.540 + 2.318\ r^{(n)} + 2.128\ r^{(n-1)}$$

$$\text{and } R = 0.755 \quad (3)$$

Damodar Bridge

Simple regression : $L_{18}^{(n)} = 288.446 + 3.798\ r^{(n)}$ (4)

$$V(L_{18}^{(n)}) = 0.02252 + 0.1219\ (r^{(n)} - .3001)^2$$

$$R = 0.545 \quad (5)$$

Multiple regression :

$$L_{18}^{(n)}(n) = 287.847 + 2.759 r^{(n)} + 3.032\ r^{(n-1)}$$

$$R = 0.683 \quad (6)$$

The 98% upper confidence limit (U.C.L.) is given by $U.C.L. = L_{18}^{(n)} - 2\sqrt{V}$, where V is the variance of the expected river level. In case of simple regression, the multiple correlation coefficient, R is same as the simple total correlation coefficient, while the correlation increases to a great extent when the rainfall on the previous day is also taken into account as in multiple regression.

Multiple correlation coefficients of all these equations equations are statistically found to be significant and as such the equations may be useful for the purpose of long range prediction of afternoon river level and hence of floods on any day with the forecast rainfall on that day, and also with the forecast rainfall on the previous day in case of multiple regression. With the the movement of storm along different tracks, the distribution of rainfall and hence an idea of average rainfall (in D.V. area) over the expected duration of the storm can be ascertained from a climatological study of past data. The problem of the classification of rainfall storms and the associated rainfall distribution over D.V. area together with the prediction of the storm rainfall is now under study.

Short-range Prediction

When a short range forecast of the river level is required, the regression equation can be greatly improved by introducing in it a few more factors like river level at 06.00 hrs. of the same station and logarithm of discharge at Palganj in case of Maithon and in addition to the logarithm of discharge at Sudamdih in the case of Damodar Bridge. The correlation coefficients (C.C.) between the river level at 18.00 hrs to be forecast and the other factors together with their mean values are shown in Table I. All the correlation coefficients are found to be statistically significant, while C.C. between L_{18} on n^{th} day and other factors on $(n-3)^{th}$ day are insignificant and are omitted from the table.

TABLE I

Factors	*Maithon*		*Damodar Bridge*		*Number of observations considered N*
	C.C.	*Mean value*	*C.C.*	*Mean value*	
$L_{18}^{\ n}$	—	349.761	—	289.586	284
$L_{18}^{\ n}$	—	349.783	—	289.620	283
$L_{18}^{\ n}$	—	349.800	—	289.651	282
$L_6^{\ n}$	0.802	349.680	0.877	289.577	284
$L_6^{\ n-1}$	0.705	349.692	0.730	289.584	283
$L_6^{\ n-2}$	0.552	349.703	0.575	289.609	282
$logd_p^{\ n}$	0.876	3.243	0.777	3.243	284
$logd_p^{\ n-1}$	0.746	3.247	0.752	3.247	283
$logd_p^{\ n-2}$	0.541	3.251	0.615	3.251	282
r^n	0.642	0.275	0.545	0.300	284
r^{n-1}	0.617	0.277	0.569	0.302	283
r^{n-2}	0.429	0.279	0.458	0.304	282
$logd_s^{\ n}$	—	—	0.871	3.604	284
$logd_s^{\ n-1}$	—	—	0.809	3.607	283
$logd_s^{\ n-2}$	—	—	0.567	3.609	282

Symbols used in this and subsequent tables are explained below :—

$L_{18}^{(n)}$ = R.L. in feet to be forecast at 18.00 hrs IST on n^{th} day.

$L_6^{(n-k)}$ = R.L. in feet of the same station as for $L_{18}^{(n)}$ recorded at 06.00 hrs.I.S.T. on $(n-k)^{th}$ day.

$r^{(n-k)}$ = Average rainfall in inches at 08.30 hrs.IST in Barakar catchment in case of Maithon or average rainfall based on stations situated on or near Damodar and Barakar rivers in case of Damodar Bridge on $(n-k)^{th}$ day.

$\log d_p^{(n-k)}$ = Logarithm of discharge (cusec) recorded at 06.00 hrs.IST at Palganj on $(n-k)^{th}$ day.

$\log d_s^{(n-k)}$ = Logarithm of discharge (cusec) recorded at 0600 hrs.IST at Sudamdih on $(n-k)^{th}$ day.

N = Total number of observations considered.

Multiple regression equations connecting the various factors considered above with the river level at 18.00 hrs. IST at Maithon and Damodar Bridge have been obtained by the method of least square. These are given in Table II.

ficant. This indicates that influence of L_6 on L_{18} of Maithon is inappreciable when average rainfall over the catchment and long discharge at Palganj is taken into consideration. This result is really of interest. The factor L_6 is therefore eliminated following Fisher[7] and the new equation is obtained as given by (1.2). A similar result has been obtained in case of Damodar Bridge in which influence of $\log d_p$ (of Palganj) on L_{18} of Damodar Bridge was found to be extremely insignificant. From the interest of comparison equation involving $\log d_p$ is also given in Table II denoted by (4.2), while in equations (5 & 6) term with $\log d_p$ has been omitted. In the last set of equations effect of L_6 is also found to be insignificant. Equation (6.2) is then obtained after eliminating this factor. In all these equations the contribution of rainfall is quite high as in the case of Maithon.

All the above equations involve both meteorological and hydrological elements. In section 2 we have obtained equations involving rainfall alone, which may be used to forecast river level on the same

TABLE II

Giving the regression equations and the corresponding multiple C.C., R and the estimate of residual variance, σ^2.

	Equation No	*Regression equation*	R	σ^2
MAITHON DAMODAR BRIDGE	1.1	$L_{18}^{(n)} = 293.192 \times 1.264\ r^{(n)} \times 2.036\ \log d_p^{(n)} \times 0.142\ L_6^{(n)}$	0.907	0.722
	1.2	$L_{18}^{(n)} = 341.672 \times 1.289\ r^{(n)} \times 2.385\ \log d_p^{(n)}$	0.904	0.740
	2.1	$L_{18}^{(n)} = 272.950 \times 1.527\ r^{(n-1)} \times 1.358\ \log d_p^{(n-1)} \times 0.206\ L_6^{(n-1)}$	0.801	1.444
	3.1	$L_{18}^{(n)} = 228.699 \times 0.950\ r^{(n-2)} \times 0.564\ \log d_p^{(n-2)} \times 0.340\ L_6^{(n-2)}$	0.590	2.652
	4.1	$L_{18}^{(n)} = 183.341 \times 0.335\ L_6^{(n)} \times 1.534\ r^{(n)} \times 0.5161\ \log d_p^{(n)} \times 1.971\ \log d_s^{(n)}$	0.932	1.193
	4.2	$L_{18}^{(n)} = 165.421 \times 1.644\ r^{(n)} \times 0.402\ L_6^{(n)} \times 2.0151\ \log d_s^{n}$	0.930	1.235
	5.1	$L_{18}^{n} = 222.100 \times 2.282\ r^{n-1} \times 0.204\ L_6^{n-1} \times 2.135\ \log d_s^{n-1}$	0.826	2.856
	6.1	$L_{18}^{n} = 258.296 \times 1.854\ r^{n-2} \times 0.080\ L_6^{n-2} \times 2.112\ \log d_s^{n-2}$	0.668	4.938
	6.2	$L_{18}^{n} = 280.233 \times 1.918\ r^{n-2} \times 2.448\ \text{lodgd}_s^{n-2}$	0.667	4.938

Forecasting formulae

The first set of equations may be used for predicting the afternoon R.L. with the date of rainfall, R.L. and discharge recorded in the morning of the same day. The second and third set of equations may be used for forecast of afternoon R.L. one and two days in advance respectively. The multiple C.C. of these equations are found by usual statistical tests to be highly significant, though for third set of equations it is less than 0.75 both in case of Maithon and Damodar Bridge. In such cases a 98% upper confidence limit (U.C.L.) may be used ; but in equations where more than two independent factors are involved, calculation of U.C.L. is rather laborious.

In equations (1.1) of Maithon, the regression coefficient of L_6 has been found to be statistically insignimorning. To forecast the river level one day in advance with the help of rainfall alone we may set up regression equation of the type.

$$L_{18}^{(n)} = a_o + a_{n-1}\ r^{(n-1)} + a_{n-2}\ r^{(n-2)} \qquad (7)$$

From the data considered the regression coefficient have been calculated and the equation took the from :—

Maithon

$$L_{18}^{(n)} = 348.493 + 2.169\ r^{(n-1)} + 2.490\ r^{(n-2)} \ ; \qquad (8)$$

$R = 0.739$

Damodar Bridge

$$L_{18}^{(n)} = 288.013 + 3.229\ r^{(n-1)} + 2.086\ r^{(n-2)} \ ; \qquad (9)$$

$R = 0.636$

The multiple C.C. have been statistically tested and found to be significant so that the equations may be used for the prediction of $L_{18}^{(n)}$ one day in advance. For forecast of $L_{18}^{(n)}$ two to three days in advance with rainfall alone an index[8] of antecedent precipitation for a longer period may be very useful.

Peak Level of the Day

So far we have attempted to predict the afternoon river level of the day. Apparently it does not account for the peak level to which the river may rise during the day or night. It is, however, found that the river level at 18.00 hrs. bears a high correlation with peak level of the day, both in case of Maithon and Damodar Bridge, while the C.C. between the river level at 06.00 hrs. and the peak level is not at all so high. This can be readily seen from the C.C. obtained from the special records on flood days for which practically hourly records of river level are available as given in Table III.

Conclusions

The results obtained in the foregoing sections take into account only the present conditions of the reservoirs and may therefore be considered to be provisional in nature as they may not be applicable when the construction of Maithon and Panchet dams is complete. The results, however, definitely suggest that similar analysis with the data obtained after the completion of all dams in the catchment will lead to fruitful result in estimating, during storms of any intensity, the highest reservoir level and peak discharge in lower reaches which are essentially required in flood control operations of the reservoirs. It is however fully realised that the run-off ratio is different for different parts of the monsoon and so analysis for each month may be attempted separately when sufficient data are available after completion of the reservoirs.

Acknowledgement

Author wishes to express his deep sense of gratigratitude to Shri A. Das, Meteorologist, for his kindness in going through and correcting the manuscript for the paper. His thanks are also due to Shri A. K. Roy Chowdhury, Senior Observer and Shri P. B. Hoare, Scientific Assistant, for the help they rendered in calculations.

TABLE III

Giving C.C. (r_m) between maximum peak level, L_m and the river level recorded at 06.00 hrs. (L_6) and 18.00 hrs. (L_{18}) on the same day and the corrected sum of squares.

	MAITHON			*DAMODAR BRIDGE*		
	L_m	L_{18}	L_6	L_m	L_{18}	L_6
Mean	354.343	353.106	352.017	296.382	295.043	294.436
Corrected S.S.	109.838	95.296	131.274	639.344	394.885	674.109
r_m	—	0.906	0.451	—	0.811	0.600
N		30			67	

A linear regession equation between L_m and L_{18} is then calculated by usual method of least squares. These are :—

Maithan : $L_m^{(n)} = 10.841 + 0.973\ L_{18}^{(n)}$; (10)
$R = 0.906$; $\varrho^2 = 0.705$

Damodar B ridge: $L_m^{(n)} = -8.250 + 1.033\ L_{18}^{(n)}$; (11)
$R = 0.811$; $\varrho^2 = 3.360$

where ϱ^2 is the residual variance which is required in equation (12). The equations are graphically represented in figure 2. The multiple C.C., R is found to be highly significant in each case. In these equations the predicted value of L_{18} obtained from the equations in section 2 & 3 may be used. Obviously, while using the predicted value of L_{18}, the error in the prediction of L_m will be slightly high, but in the absence of other alternatives, this will give a good idea of the maximum peak level and hence of the flood at these stations. In case of forecast of L_m for the night or next early monrning, day's actual value of L_{18} can be used in the above equations which will lead to a quite accurate value of L_m. The 98% U.C.L. of L_m for this equation may also be obtained from the relation :

$$\text{U.C.L.} = L_m + \left[\frac{1}{n} + \frac{(L_{18} - \bar{L}_{18})^2}{S^2_{18}}\right]^{\frac{1}{2}} \times 2\varrho \qquad (12)$$

where S^2_{18}, the corrected sum of squares of the observed L_{18}, and $\bar{L}_{18}$ s mean and n=30 for Maithon and 67 for Damodar Bridge are given in Table III and L_m is the estimated value of the peak river level by equation (11) or (12).

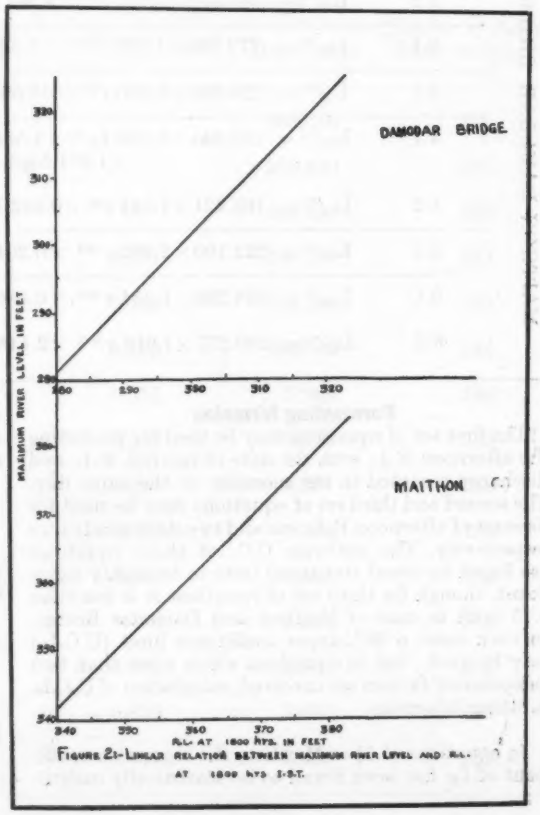


FIGURE 2:- LINEAR RELATION BETWEEN MAXIMUM RIVER LEVEL AND RI... AT 1800 HRS I.S.T.

Drainage Study of Lower Damodar Valley—III

By SATYAKAM SEN, M.A.

The effectiveness of a stream, in the matter of transportation of the debris from erosion, depends, apart from its gradient, on the volume of water as well. High flood discharge is therfore greatly faavourable to the carrying over sedimentary matter by the discharging stream. It is therefore obvious that when the discharge of water by the tributary streams is great under high flood condition, the detritus carried by these streams should find its way into main river into which they disgorge. As a result, the sedimentary matter carried by this main river itself will be added to what is brought up by the tributary streams. On account of an augmented supply of sedimentary matter thus provided, the bed of the main river will naturally riser. This kind of phenomenon constitutes a problem for the lower reach of Damodar.

Sediment source

The Damodar river system carries considerable amount of suspended load with its flow. The suspended load carried by Damodar river is obtained from the upper catchment basin. Erosion there is of an extensive order. Careful examination of air-photographs and recent survey maps reveals that the Chotanagpur plateau is dotted with alarming preponderance of gully erosion; and increase of perimeter of eroding bank caused by the rapid widening of the trough, along recently cut gully, is also prevalent. The main causes of soil erosion in the Chotanagpur plateau have been deforestation, over-grazing, forest fires, unscientific cultivation and mining.

The sediment of upper valley invades the lower valley with rushing torrents during the monsoon season. Most of the bedload of coarser type falls early but the finer particles as the suspension load are deposited in the lower reach.

Suspended load in the Lower Damodar River System

Silt charge stations are few in number in the lower reach. Data of only two stations are available since 1953 namely Mohiddipur (Damodar) and (Kaki). These have been taken into consideration for comparison with the Damodar Bridge site. Two more stations have been added in the distributary channels of Damodar in 1955.

The volume and intensity of the suspended load for the years 1953 and 1954 have been expressed in acre ft. in the tables. The statement available is only for the monsoon months. In pre- and post-monsoon the river channel become dry. The surface currents are feeble, and sometimes nil. Hence the suspended load could not be worked out for during these periods, and, in view of the above circumstance, may be considered as practically non-existent.

An appreciable amount of silt is found at the Damodar Bridge site on Damodar river as well as at Mohiddipur or river Kaki during the monsoon period. The amount of silt charge is very small, being negligible at Mohiddipur (on Damodar river). As most of the Damodar flood water passes through Kaki river, the considerable amount of silt charge take place through it, whereas Damodar river (at Mohiddipur) carries only an insignificant amount of silt.

The suspended load was found to consist of a high amount between June and October for all the three stations, Damodar Bridgesite, Mohiddipur (both Damodar & Kaki). Such load is relatively high in Mundeswari (at Harinkhola) compared with the drainage channels like Harinakhal (at Rautara) and Kabla N. (at Mayapur.) It shows (see table) that the amount of the suspended load varies with discharge and velocity, from the upstream. It also varies with the intensity of flood.

From the study it is clear that the suspended load is high in the eroding river of the Damodar. This compares well with the phenomenon observed with the Mayurakshi river

Tidal characteristics

Tides play a very important part in the estuarine channels of Damodar. The influx of tidal water brings sediment and it also influences salinity to a great extent. The problem here is to find out the approximate limit of the tidal influence in the lower reach of Damodar.

Source Material

In all the outfall channels, the hydro-meteorological sites are meagre in number. To find out the tidal limit, 6 stations, viz, Amta (on old Damodar), Kharagharhai (on Hoorhoora Khal), Gaighata (on Gaighata), Baxi (Rupnarayan R), Baligori (confluence of Kata khal and Mundeswari) and Bans beria (old Damodar) have been taken into consideration.

All these stations are gauge observation sites At Amta raingauge data are also available. For comparison with the upland discharge and its influence on demarcating the tidal limit, two stations, Mohiddpur (Damodar) and Mohiddipur (Kaki), have been considered for study. The year selected for discussion of the data is 1944.

Amta— Two High water level peaks are observed every month except during the monsoon period (*ie.* Mid-July to Sept). In pre and post monsoon periods, the high water level marks attain a proper shape. The time lag between these two peaks is approximately 15

Photo No. 15—Tides in Lower Damodar 3 miles below Amta.

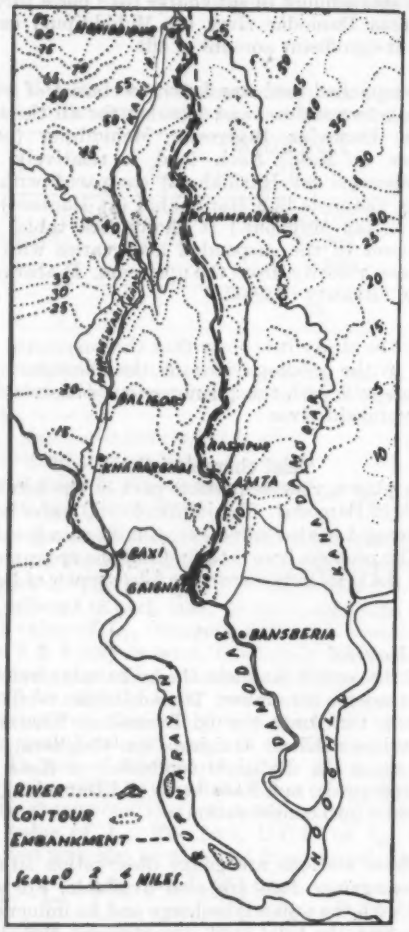


Fig. 38

days i.e. a fortnight. This clearly shows that phases of the full and new moon have got the dominating influence on the high water level marks at Amta. But during the monsoon months the distinctive features common to the pre and post monsoon periods are absent. High water level marks seem to be continuous particularly in the month of September ; in this case, high and low water level marks reveal the influence of upland flood discharge. Regarding low water level marks, it is observed that the fluctuation is more or less steady. These marks rise considerably during the monsoon months.

Bansberia—Alternating peaks and valleys of high water level marks are observed throughout the year. The shape of the high water level marks appears to be round. The time lag between the two peaks points one again 15 days approximately. The nature and type of the curves for high and low water level marks are more or less the same throughout the year. The curves clearly indicate the tidal influence is prominent at Bansberia. In the month of August the high water level marks are more or less steady but the low water level marks continue to rise.

Baligori—The difference between the high and the low water level marks is negligible during pre and post monsoon periods. The difference is only marked during the monsoon. During the monsoon period, the high and low water level marks both fluctuate.

*Kharargha*i—Curves are very irregular. No periodical rise or fall is observed as in Amta and Bansheria gauge sites. Both the high and low water level marks fluctuate throughout the year. The fluctuating nature its .lf suggests that influence of tides is very dominant at this station. Influence of fresh upland discharge is apparently small.

Baxi—'Ups' and Downs' in the curves are found during the monsoon season. Fluctuation is more in early September, But thereafter it settles down to its normal state.

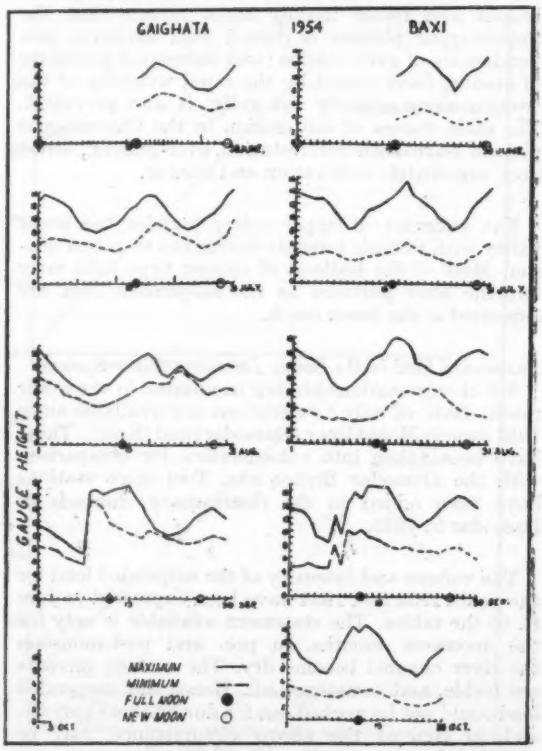


Fig. 39

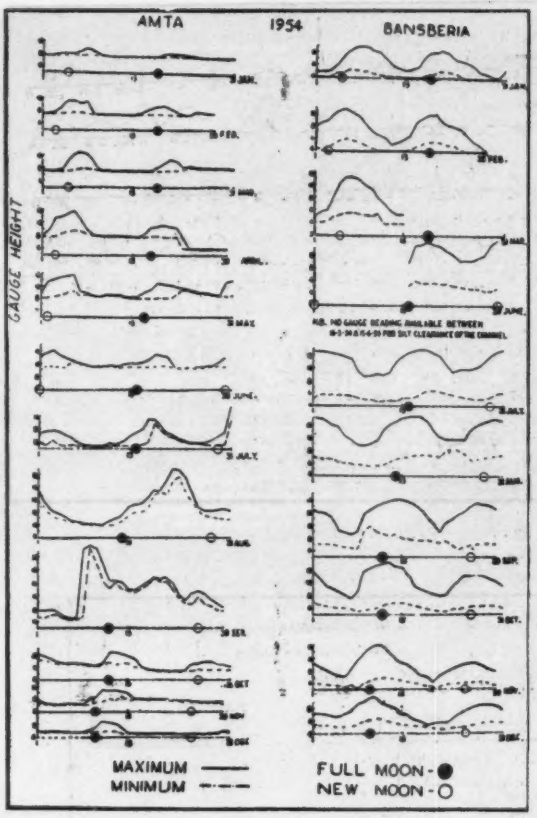


Fig. 40

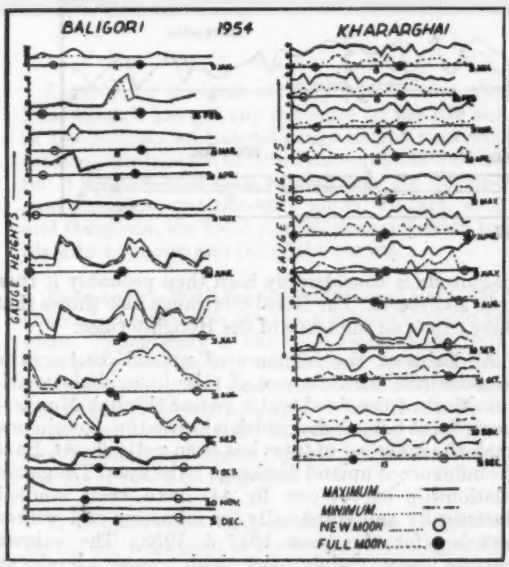


Fig. 41

Gaighata—Gauge curves of Gaighata are similar in trend to what is observed in Baxi. A sudden rise is indicated by the steepness of the curve, which occurs in the month of September. Subsequently the curve descends gradually and takes its normal shape.

Differences in High and Low Water Level marks—The range of fluctuation can be ascertained from the difference between the high and the low water level marks. (See fig. 42)

Amta—The rise in the difference of level in pre and post monsoon days is found at certain regular intervals. This factor clearly indicates that the phases of the moon predominantly influence the rise and fall of the tides.

In the monsoon season the curve gets disturbed by the influence of the upland flood discharge.

Bansberia—An alternate rise and fall of the curve is seen. The influence of the phases of the moon is thus reflected on the curve. The main thing seems to be the influence of upland discharge being the least. The same trend is observed in the curve throughout the year.

*Kharargha*i—The curve is irregular. The nature of the rise and fall of the curves during the pre and post monsoon seasons depicts the influence of the tides. During the monsoon months however, the influence of upland discharge is felt.

Baligori—The range is very insignificant. With the incidence of the rains, the curve rises. This rise in the curve is considerable during the period from June to September which indicates the influence of upland discharge.

Gaighata & Baxi

Data available for study of these two stations cover the monsoon months only. The curves appear more or less in rounded form. No prominent peaks are visible. Both the rise and the fall of the curve appear to be of steady nature. The influence of tides is however clear.

Upland discharge & Stage fluctuation

In Mohiddipur (on river Damodar) & Mohiddipur (On river Kaki) gauge sites are located. So it is possible to discuss with reference to the observations made in these stations whether the upland discharge has got any influence on the gauge sites of the tidal reach.

In this connection we must remember that most of the upland flood discharge passes through Kaki river and only a small fraction through the old Damodar channel below Mohiddipur bifurcation. Thus the old Damodar channel is feeble ; and the sides gradually push upwards makihg the tidal limit penetrate inwards.

Mohiddipur (Damodar)	*Amta*	*Gaighata*	*Bansberia*
Date			
16th-18th July	16th-21st July	12th-23rd July	13th-23rd. July
15th-26th Aug.	15th-26th Aug.	9th-26th Aug.	11th-21st. Aug.
7th-23rd Sept.	7th-24th Sept.	8th-22nd. Sept.	7th-21st Sept.

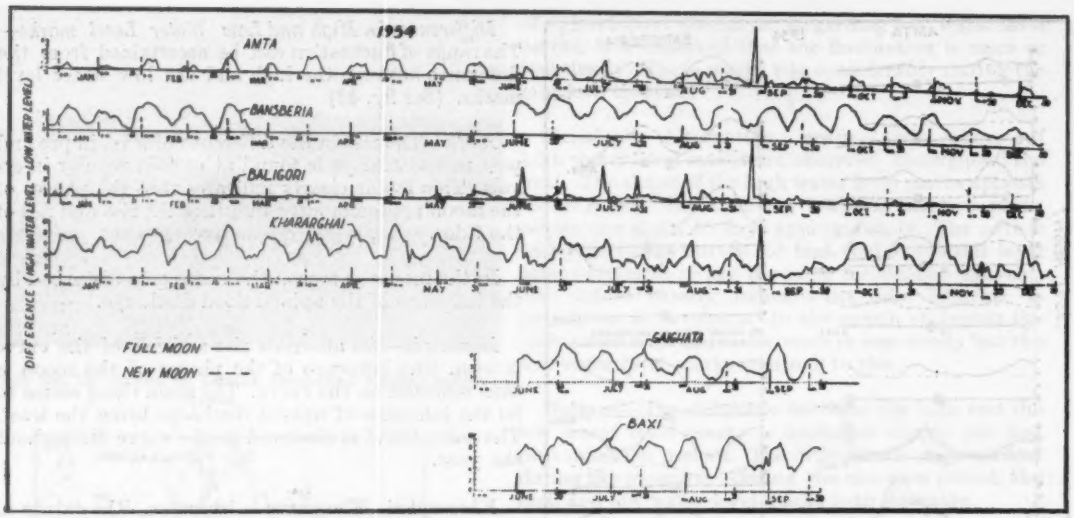


Fig. 42

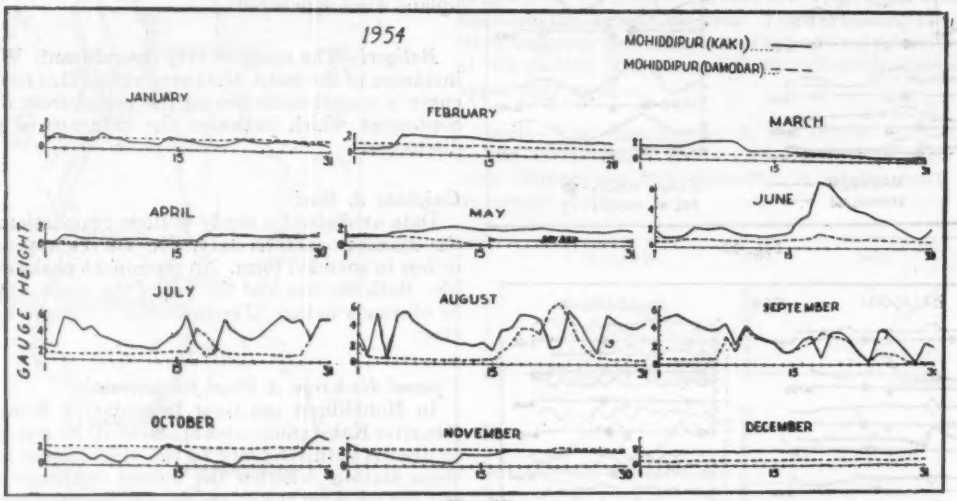


Fig. 43

Mohiddipur (Kaki)	*Baligori*	*Khararghai*	*Baxi*
Date			
14th-29th June	14th-23rd. June.		
	13th-21st. July.		
2nd-26th Aug.	9th-29th Aug.		
14th-28th Sept.	1st-27th Sept.	4th-17th Sept.	5th-20th Sept.

From the above table it is clear that when the upland discharge is considerable at Mohiddipur (Damodar) the portion of its flood water reaches Amta and sometimes goes down to Gaighata. If the magnitude is considerably high then probably it runs upto Bansberia. The Bansberia gauge also shows that there exists an influence of the Hooghly tides.

At Baligori, the influence of upland discharge is considerable, the influence of tides being slightly visible. Most of the flood water passes through Mundeswari. So, at Khararghai which is located on Hoorhoora khal, the influence of tides has been noticed. At Baxi the influence of upland discharge is the least. The gauge relationship curves (see fig 44) have been studied statistically and graphically for monsoon and winter periods (for the year 1952 & 1953). The salient features are mainly the high water level at Khararghai (on Hoorhoora khal) can be correlated with Dainan (which is tidal) on the Rupnarayan R. during dry season; that there is no relationship between the water levels of Baligori and Khararghai; and that, the daily mean water levels at Khararghai and Baligori can be correlated with that of Mohiddipur on R. Kaki during monsoon months (July to October).

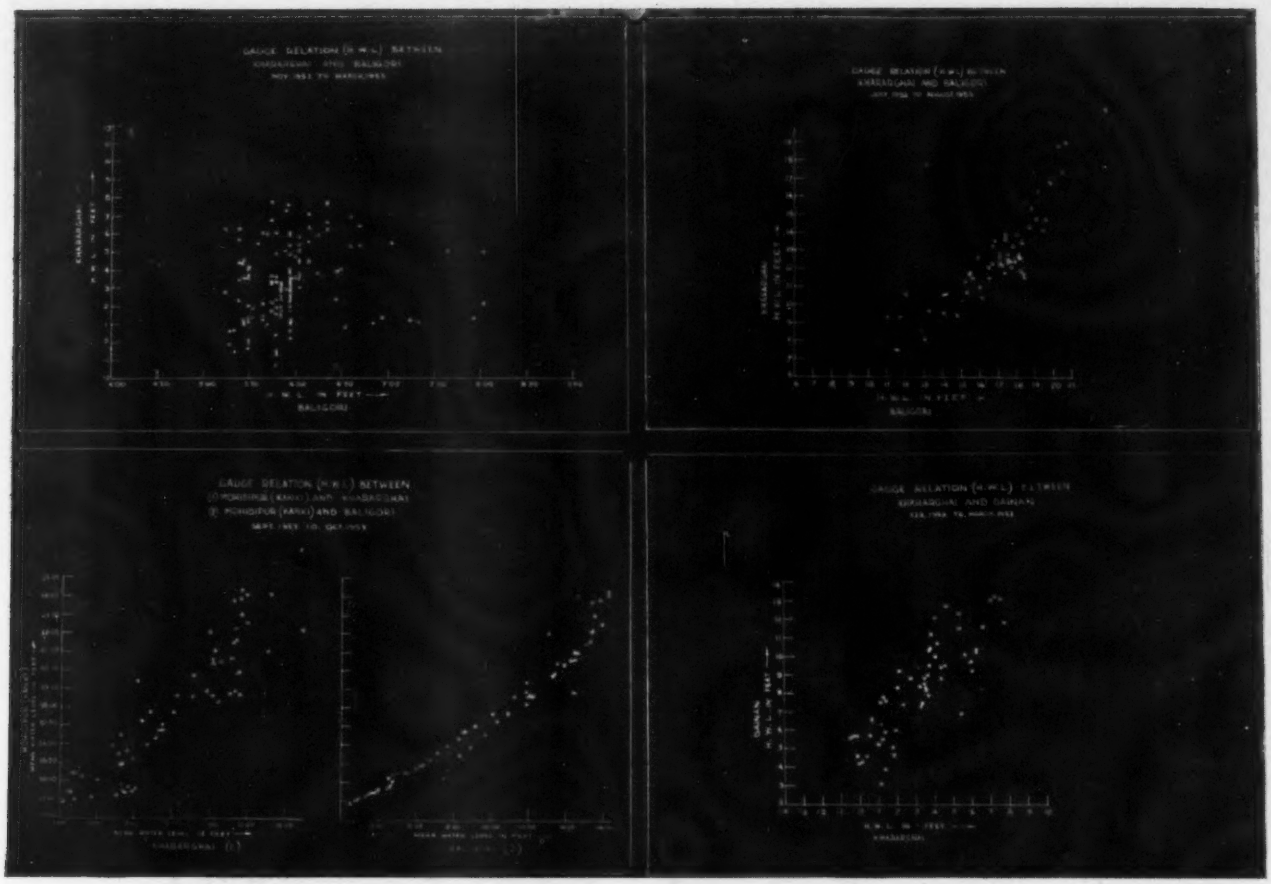


Fig. 44

Influence of Rainfall—It may now be seen whether local rainfall has got any influence on the rise and fall of the gauges. At Balgori gauge height rises with increasing rainfall (5th to 10th June—rainfall 4.60 inches) So, it appears that local rainfall has got influence on gauge heights, but not very much. In fact, at Amta and Gaighata, the local rainfall does not seem to visibly affect the rise and fall of the curves.

Discussion—With the deterioration of Damodar river channel, considerable extension of tides has been taking place. Topography of the tidal reach shows that the area isl ow and slightly undulating. In this reach, the low topography, and existence of a network of channels and drainage lines in some places lead to marshy lands. It is found that the tidal waters coming from Hooghly and Rupnarayan reach, spread at the extremity of the lower reach of Damodar.

It is observable that in Bansberia, Gaighata and Baxi,, the behaviour is positively a tidal one. During the dry season when there is no upland discharge, the gauges of Bansberia are governed by the tidal inflow. Here the upland discharge, when the magnitude of the flood is considerably high, would affect the gauges, not otherwise. During the flood season the upland discharge supercedes the effect of the tides. The tides push upto Amta along Damodar river. As the upland discharge has become more feeble after the construction of dams at the upper reach, the tides keep on pushing upwards. As Kharagharhai is located on the bank of Hoorhoora Khal and as most of the Damodar flood water is flowing through Mundeswari and passing through Chaubisbigha Khal, falling ultimately into Rupnarayan, the tidal water penetrates through Hoorhoora bringing about the tidal fluctuations which have been observed at Kharagharhai. At Baligori the tidal influence is the least while the effect of upland discharge is noticeable.

Fluctuation of Ground Water-Table

The part of the rain water that soaks into the earth, under the present circumstances, is the main source of sub-soil water-supply. The location and movement of ground-water are largely determined by soil composition and geological formation. It is a known fact that perennial irrigation very often leads to water-logging. A good quantity of irrigation water, in Punjab, is lost by seepage from irrigation canals and reaches the underground water-table ; and even part of the water supplied to agricultural fields, is not utilised by crops but goes down from this' Pellicular zone" to the "Capillary zone," and thus raises the water-table. This rise of the underground water-table leads to water-logging and makes low-lying agricultural tracts uncultivable. The problem is sometimes being aggravated by construction of canals, embankments and field-bunds for irrigation. In Punjab, according to the 1945 survey,

the estimate of water-logged lands was about 50,527 acres.

The study of ground-water table fluctuation in relation to the water logging problem of the Lower Reach of Damodar is very important.

Source Material

The irrigation Department of the Government of West Bengal have maintained a record of the Pre-monsoon (April) and the post monsoon (October) depths of the water-table of open wells at selected places over the Lower Reach of Damodar. But these recorded observations do not give a complete picture of any long-trend fluctuations that occur because no continuous record for a single well, or even any record of all the wells, is available. Only a broad idea about short time fluctuations and the general nature of the water-table may be obtained from these data.

Recently D.V.C. has undertaken a scheme for water-table survey in the Lower Reach of Damodar in order to study the present conditions of ground water table. The scheme of water table survey has been drawn up by D.V.C. and 30 piezometer tubes of 27 stations have already been sunk in 1954. The data from the piezometer observations have been received for our examination. Along with these, the analyses of the soil for different depths have also been obtained.

Trend of Fluctuations from well observations (1933-49) —The region concerned can be conveniently divided into three following zones from the observations of wells. The charcteristic features are enumerated below:-

The pre-monsoon & post-monsoon fluctuations of water table are well observed from the ground water contour map showing the differences of April and October water table. (see map No. 45) The range is

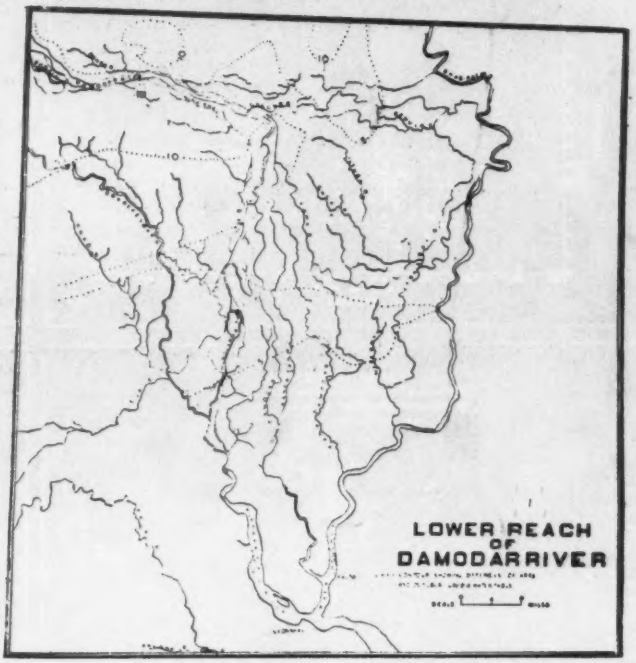


Fig. 45

Zones	*Area Served*	*Characteristic Features*	*Possibilities of Water Logging*
I	Northern part of Howrah District between River Damodar and River Hooghly.	Shallow depth of watertable from surface. In general, High water-table prevails; little fluctuation between Pre & Post monsoon depth of water table.	Chances of water-logging.
II	S. E. of Burdwan-Katwa railway line (Jamalpur and Pandua P.S. of Hooghly District Memari, Monteswar and Katwa District). Dead rivers of Behula and Gangpur passes through this tract.	Do	Do
III	West & S.W. West of Burdwan-Katwa Rly. line (P.S. of Ausgram, Mangolkot & Galsi of Burdwan.)	The Groundwater table is well below the surface level. Pre & Post monsoon water-table fluctuation is very high.	Least possibilities of water logging.

From the above table it is observed that in zones I & II water logging possibilities prevail and due to to this fact, these zones require thorough investigation of groundwater table fluctuations, so that it would may be possible to demarcate correctly areas that are likely to be water logged.

The rise of water table takes place with the monsoon rainfall. In June, following a long dry period, the water table is at its greatest depth from the surface. In October, following the monsoon period, the water table is at its minimum depth from the surface.

higher in the north west and lower towards the south east. The fluctuation rate of ground water table is small between the pre & post monsoon periods in zones I & II. The range of water table rises high, as we proceed towards west and north west, with the rise of relief. The variation of relief is slight between Damodar and Hooghly rivers.

Topography and water table

Water table fluctuation and the topographic features should be studied in detail in order to ascertain the actual water logged areas.

Slight topographic undulations or relief depressions with bad drainage conditions might lead to water logging. The water table is usually high near the river. This is possibly due to the fact that the supplies in the river are high during rainy season. The volume of water which overtops the banks and is spilled, atleast a large part of it, never returns. It remains standing in depressions and low lying areas near the rivers.

Trend of Fluctuations from Piezometer Observations

Water table fluctuations as observed from piezometer pipe show that the rise and fall are well related to rainfall. The data collection in the year 1954-55 began from the month of May, 1954 i.e. during the pre-monsoon period. It is a known fact the peizometer pipe (after it is sunk) takes time to allain its normal shape. Particularly in lower reach of Damodar where soil texture is not homogenous the pieremeter reading are likely to take time to become steady.

Water table fluctuation is very sensitive to rainfall. Its behaviour is different in the pre-monsoon and the post-monsoon periods. The records of the different water table stations show that during monsoon the water table rises, and reaches its peak about the early part of October, (i.e. at the end of the monsoon period). In Post-monsoon season the water table drops steadily.

The data for 1955 reveal that in the month of June the water table sinks to a low level. The data from the different water table stations show close relationship in their rise and fall with the change of rainfall (see fig. 46). The following chart also indicates the relationship between rainfall and rise of watertable at certain sites.

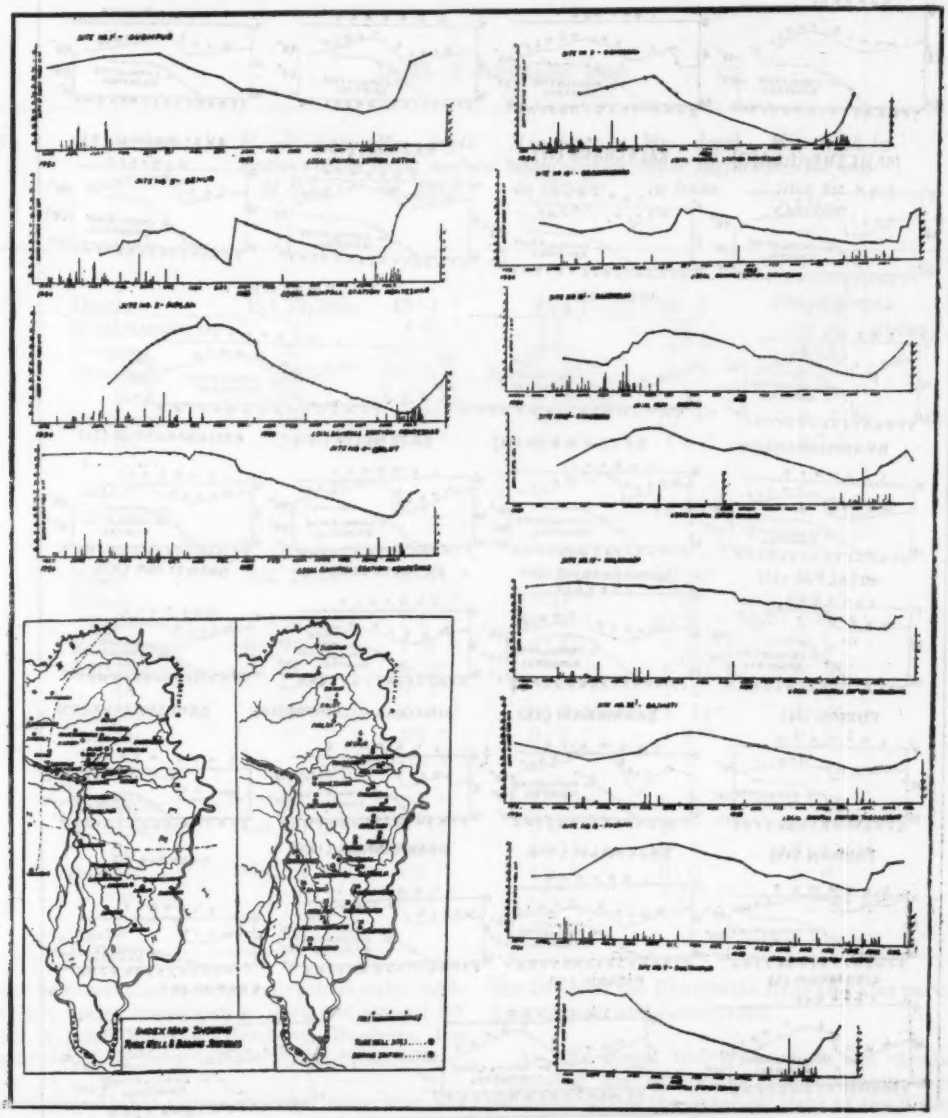


Fig. 46

Site No.	*Location*	*Observations*
4	Kalut	Progressive falls of the ground-water levels upto June and then increases in July, 1955.
17	Kalachara	
1	Sudhpur	Water table comes to the surface level following heavy rains in August and October (1955)respectively and the lands become water logged, presumably due to bad drainage.
23	Baneswarpur	
21	Krishnaram-pur	
14	Dastanpur	Water-table comes to the surface-level following heavy rains in the year 1954 and
15	Paunan	

It also appears from the graph (see fig. 47) that the rate of rise of water-table is much faster than the rate of precipitation in the area under investigation. The amount of water causing the rise of water-table adds to more than the accumulated rainfall. This reason is probably due to seepage flow from outside the area concerned. According to Bose,[19] "if the porosity of the subsoil is about 35 to 40% then the actual rise of water-table can be expected to be almost equal to the accumulated height of the rainfall, during the same period."

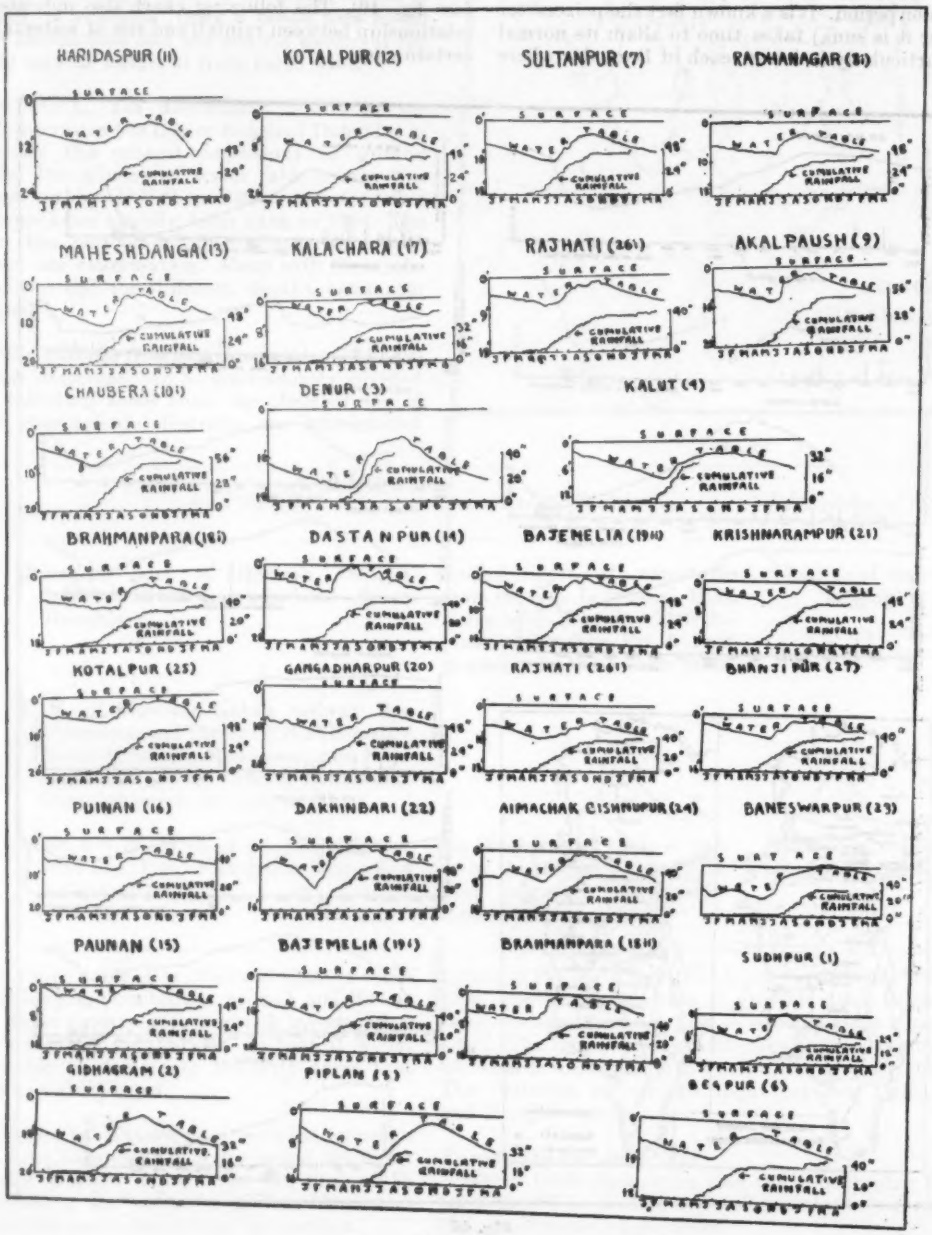


Fig. 47

The following table will give an impression about the response of ground water table to rainfall.

Rainfall	*Near Pipe Nos.*
3″ to 4″	1, 2, 3, 22, 23, 24 and 26
6″ to 8″	5, 9, 21 and 25
14″ to 18″	14, 16, 17, 18, 19, 20 and 27

Unless the following accumulated rainfall is found in the water table of following does not respond. This shows that surface drainage in these areas differ considerably and the water table also is very sensitive to the surface run off capacity of the different areas.

The maximum depth of water table from the surface in D.V.C. commanded area is about 16ft. and the minimum depth of water-table sometimes reaches ground level in the month of October after rainy season.

south-east (Following the regional trend of the relief surface slope). In pre-monsoon (15th May) time the contours are more or less widely spaced and regular. Irregularities begin with the burst of the monsoon (fig. 48).

Probable areas of Water-logging

Ground water slope from Arambag to Baidyabati (from well observations) shows that the water table (in October) approaches the ground surface as the ground surface slope decrease (see fig. 49). Near Gopalnagar, as fall of surface level occurs, the rise of water table in October offers a possibility of water logging. It is clearly seen (fig. 50) that the present water logged sites are mainly found in the topographical depressions. As the general water table condition rises along with the rise of the amount of rainfall, the relief depressions may offer possibilities for future water logging sites. These depressions occur just along

Depth of watertable 1955

No.	*Stations.*	*Height of the stations above M.S.L.*	*Ma . depth below surface in April*	*Min.depth be below surface in October.*	*Ma . depth below surface in fiune.*	*Min depth be- low the sur- face in October*	
3	Denur	Bet 33-38ft.	15′-1 ′	6′-4 ″	16′ 2 ″	5′-11 ″	
21	Krishnarampur	10′	4′84 ″	1′1 ″	7′ ″	0′ 4″	above G.L.
16	Puinan	32′	7′3 ″	2′9 ″	8′ 3″	4′ 2′	
101	Chaubera	40′	7′7 ″	1′ 8″	8′ 9 ″	3′ 3 ″	
10ii	do	40′	6′8 ″	0′ 0″		0′ 7 ″	
19i	Bajemelia	24′	9′5″	6′1″	10′ 0″	6′ 7 ″	0′9 ″
19ii	do	24′	6′9 ″	1′4 ″	1′4 ″	8′7 ″	
2	Gidhagram	58′	12′7″		13′10 ″	4′ 6 ″	
5	Pillan	bet. 38-48′	8′-11 ″	0′-3 ″	10′10″	2′11 ″	
4	Kalut		5′10 ″	0′11 ″	7′7 ″	3′ ″	
7		8′8″	1′6 ″	10′ 1 ″	10′ 1 ″	3′ 2 ″	
8i	Radhanagar	bet.34-36′	7′-9 ″	2′ 1″	8′ 5 ″	2′ 9 ″	
1i	Sudhpur	38′	6′ 2″		6′ 11 ″	0′ 3″	
1ii	do	38′	6′ 5 ″		7′ 2″	0′ 4 ″	
17	Kalachara	32′	2′ 5 ″	0′ 6 ″	4′ 11″	1′ 1″	
15	Paunan	22′	3′3 ″ (above G.L.)	0′ 2 ″	4 6 ″	0′ 1 ″	
27	Bhanjipur	36′	5′4 ″	1′ 3 ″	6′ 7 ″	1′ 11 ″	
18i	Brahmanpara	bet. 30′-32′	8′ 11″	5′8 ″	9′ 7 ″	3′ 7 ″	
18ii	do	do	6′3″	3′ ″	6′ 7 ″	0′ 5 ″	
26i	Rajhati	bet. 28-30′	8′2 ″	4′4 ″	9′ 6 ″	5′ 6″	
26ii	do	do	5′11 ″	2′0″	7′1 ″	1′4 ″	

It may be noted that maximum depth of water table in the area under investigation does not exceed 20′ whereas in some parts of Burdwan, Bankura, the maximum depth of water table is about 40′ to 45′.

Ground water-table contours (1955) show that the water-tables (fig. 48) slope is from north-west to

the fringe of the Bhagirathi river and also particularly near the old and dead rivers.

At this stage, the predication and demarcation regarding the spread of water-logging cannot be be made unless the detailed data of the distribution of clay pans, silts and sands are available.

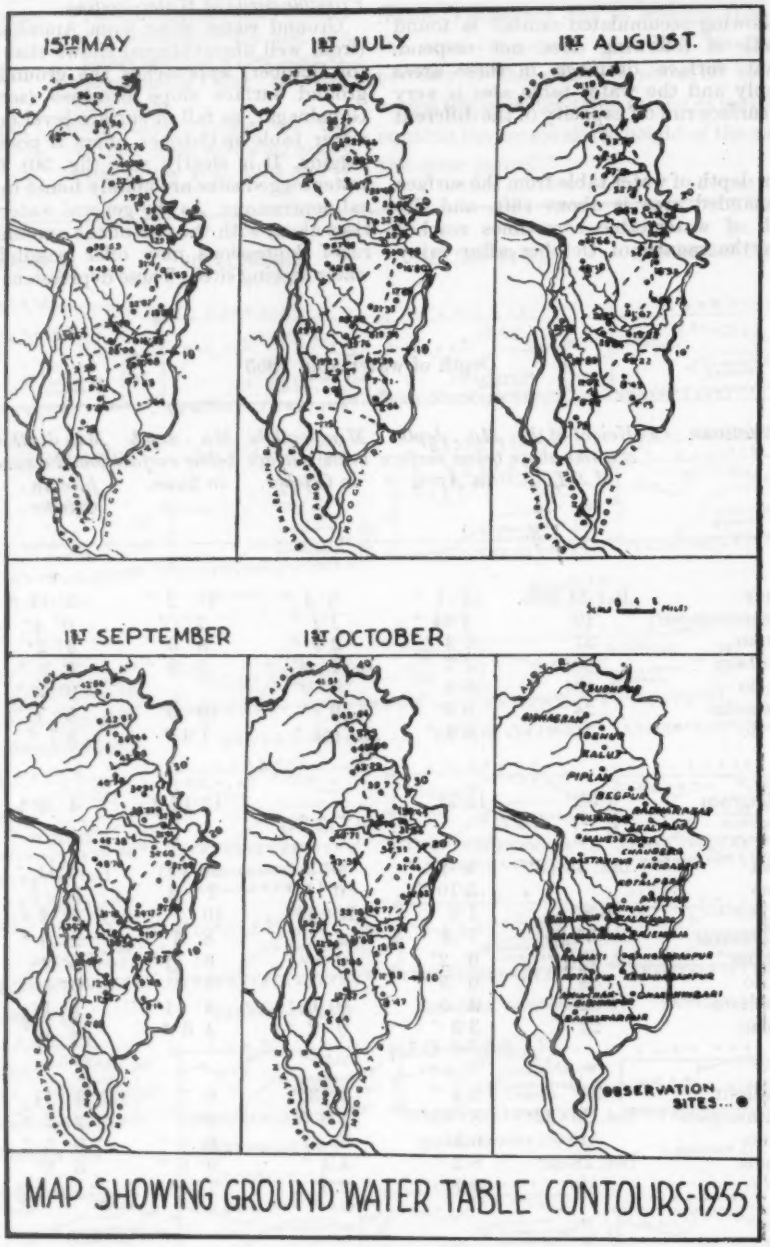

15TH MAY
1ST JULY
1ST AUGUST.
1ST SEPTEMBER
1ST OCTOBER
OBSERVATION SITES...
MAP SHOWING GROUND WATER TABLE CONTOURS-1955

Fig. 48

TABLE 5

FREQUENCY

ASANSOL 1953	0·50-0.74	0.75-0·99	1.00-1.24	1.25-1.49	1.50-1.74	1.75 1.99	2.00-2.49	2.50-2.99	3.00-2.99	3.50-3.49	3.50-3.99	4.00-4.49	4.50-4.99	> 5"	rf. (inch)	1954	0.50-0.74	0.75-0.99	1.00-1.24	1.25-1.49	1.50-1.74	1.75-1.99	2.00-2.49	2.50-2.99	3.00-3.49	3.50-3.99	4.00-4.49	4.50-4.99	≯ 5.00	rf (inch)	
Jan	2		1	1																			1							Jan
Feb																														Feb
Mar																														Mar
April			1																											Apl
May			2	1	1													1		1			1	1						May
June	1	5			2		2										1	2	1		3									June
July	9	3	6	3	2												1	3	3	1		1	1		1					July
Aug	7	7	9	3	6	1	2						1	1				3	1		1	1	1	2						Aug
Sept	7	4		2	2	1	2										3	4	5	1				1						Sep
Oct		2			1														1	1										Oct
Nov	1			1																										Nov
Dec																		1												Dec
Total for year	27	21	19	11	14	2	6						1	1			5	14	11	4	4	2	3	5	1					Total for year

TABLE 6

ASANSOL

1952	Raw Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
10th July	0.62		0.01	0.02	0.44			0.02													0.07	0.05			0.01
11th July	0.56													0.08			0.18		0.28	0.02					
12th July	0.59													0.47	0.02	0.03					0.07				

1953—4th, 5th, 6th July

	Duration	*Amount (inches)*	*Intensity in 1 hr.*	*Falls in successive 5 minutes r. f. (cents)*																
				1	2	3	4	5	6	7	8	9	10	11	12					
4th July 1953	2035-2045	0.15	0.90	8	7										5					
5th July 1953	0215-0425	3.03	1.40	5	8	24	10	16	14	6	5	5	5	5		13	22	20	10	34
				16	24	12	14	6	5	5	6	8								
,,	0622-0632	0.20	1.20	12	8															
6th July 1953	1227-1232	0.05	0.60	5																

1954—7th, 8th Sept.

	Duration (inch)	*Amount*	*Intensity in 1 hr*	*r. f. in successive 5 minutes (cents.)*																
				1	2	3	4	5	6	7	8	9	10	11	12					
7th Sept. 1954	0030-35; 0040-45; 0050-55; 0100-20; 0135-45; 0400-05; 0415-55; 0950-1025; 1510-1520.	3.20	1.42	0.10	0.22	0.30	0.10	0.10	0.16	0.18	0.07	0.14	0.16	0.29	0.26	0 08		0.14		0.6	0.8	0.10
				0.10	0.10	0.10	0.20	0.10	00.6	0.08	0.06											
8th Sept, 1954	1145-50; 1515-20,	0.15	0.90	0,05	0,10															

TABLE 7

MONTHLY AVERAGE VALUES OF EVAPORATION IN INCHES

Station according to height.	*January.*	*February*	*March.*	*April.*	*May*	*June.*	*July*	*August.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Overall range of variation.*	*Max. evap. for diff. months. in Inches*	*Main. evap. for diff. months. in Inches*
1. Hazaribagh 2019 ft.	0.16	0.25	0.40	0.60	0.51	0.19	0.08	0.07	0.06	0.13	0.18	0.15	0.85	0.86	0.01
2. Barhi 1300 ft.		0.26	0.41	0.63	0.55	0.19	0.10	0.08	0.08	0.16	0.28	0.15	0.80	0.81	0.01
3. Ramgarh 1069.71 ft.	0.1141	0.1860	0.2986	0.4418	0.4180	0.1707	0.0902	0.0662	0.0570	0.1033	0.1304	0.1063	0.57	0.58	0.01
4. Dhanbad 815 ft.	0.17	0.26	0.40	0.60	0.43	0.16	0.11	0.09	0.08	0.13	0.18	0.16	0.84	0.84	0.001
5. Bokaro 784 ft.	0.131	0.201	0.329	0.529	0.451	0.172	0.114	0.097	0.093	0.115	0.153	0.128	0.69	0.71	0.02
6. Panchet Hill 391 ft.	0.182	0.291	0.508	0.7731	0.167	0.46	0.136	0.1085	0.088	0.155	0.0186	0.146	1.10	1.13	0.03
7. Asansol 414 ft.	0.160	0.248	0.420	0.595	0.464	0.196	0.113	0.093	0.085	0.132	0.169	0.147	0.81	0.82	0.01
8. Alipur	0.087	0.143	0.198	0.193	0.143	0.79	0.073	0.055	0.062	0.082	0.109	0.091	0.30	0.30	0.00

TABLE 8

Monthly Maximum values (In inches)

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May.*	*June*	*July*	*August*	*September*	*October*	*November*	*December*
Hazaribagh	0.22	0.37	0.54	0.85	0.86	0.47	0.17	0.15	0.21	0.23	0.23	0.24
Barhi		0.35	0.55	0.76	0.81	0.49	0.17	0.15	0.15	0.30	0.29	0.21
Ramgarh	0.16	0.25	0.45	0.54	0.58	0.34	0.18	0.12	0.15	0.13	0.17	0.18
Dhanbad	0.24	0.36	0.53	0.84	0.67	0.29	0.28	0.16	0.23	0.23	0.22	0.24
Bokaro	0.17	0.30	0.46	0.71	0.70	0.32	0.26	0.17	0.18	0.18	0.24	0.22
Panchet Hill	0.28	0.42	0.94	1.13	1.03	0.41	0.23	0.19	0.14	0.30	0.29	0.30
Asansol	0.25	0.31	0.64	0.82	0.73	0.38	0.23	0.16	0.15	0.22	0.24	0.22
Alipur	0.12	0.19	0.26	0.30	0.23	0.15	0.12	0.11	0.12	0.14	0.18	0.14

TABLE 9

Monthly Minimum values (in Inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	August	September	Octoher	November	December
Hazaribagh	0.07	0.14	0.12	0.42	0.20	0.04	0.01	0.01	0.02	0.01	0.13	0.03
Barhi		0.11	0.26	0.40	0.28	0.04	0.02	0.01	0.03	0.02	0.16	0.05
Ramgarh	0.06	0.12	0.16	0.37	0.24	0.05	0.02	0.02	0.02	0.01	0.09	0.04
Dhanbad	0.04	0.17	0.11	0.46	0.22	0.05	0.02	0.00	0.03	0.00	0.12	0.05
Bokaro	0.11	0.13	0.07	0.39	0.20	0.03	0.02	0.02	0.02	0.06	0.10	0.05
Panchet Hill	0.04	0.16	0.27	0.48	0.20	0.06	0.03	0.03	0.04	0.03	0.11	0.03
Asansol	0.08	0.15	0.22	0.43	0.21	0.05	0.03	0.01	0.03	0.02	0.09	0.04
Alipur	0.03	0.09	0.00	0.12	0.06	0.02	0.01	0.01	0.00	0.00	0.09	0.01

TABLE 10

Monthly range (in Inches)

	Jan.	Feb.	Mar.	Apr.	May.	June	July	August	September	October	November	December
Hazaribagh	0.15	0.23	0.42	0.43	0.66	0.43	0.16	0.14	0.09	0.20	0.10	0.21
Barhi		0.24	0.29	0.36	0.53	0.45	0.15	0.14	0.12	0.28	0.13	0.16
Ramgarh	0.10	0.13	0.29	0.17	0.34	0.29	0.16	0.10	0.10	0.14	0.08	0.14
Dhanbad	0.20	0.19	0.42	0.38	0.45	024	0.25	0.16	0.12	0.23	0.10	0.19
Bokaro	0.06	0.17	0.39	0.32	0.50	0.29	0.24	0.15	0.16	0.12	0.14	0.17
Panchet hill	0.24	0.26	0.67	0.65	0.83	0.35	0.20	0.16	0.10	0.27	0.18	0.27
Asansol	0.23	0.16	0.42	0.39	0.52	0.33	0.20	0.15	0.12	0.20	0.15	0.18
Alipur	0.09	0.10	0.26	0.18	0.17	0.13	0.11	0.10	0.12	0.14	0.09	0.13

TABLE 11

Record High Peak flows in Damodar at Phondia

Flood	*Run-of in inches*	*Flood peak in Cusecs.*
11th to 15th August, 1935	3.35	700,000
5th to 8th October, 1936	1.50	323,000
27th August to 2nd September, 1940	2.39	381,000
9th to 13th October, 1941	2.98	642,000
7th to 14th August, 1942	3.71	394,000
15th to 20th July, 1943	2.46	414,000
26th August to 29th August, 1944	1.68	153,460
3rd August to 6th August, 1946	0.81	130,497
3rd to 5th September, 1947	1.46	359,567
21st July to 25th July, 1949	2.00	137,027
16th August to 20th August, 1949	1.02	141,385
17th July to 21st July, 1950	1.52	199,129
2nd August to 6th August, 1950	1.08	150,071
11th August to 14th August, 1950	1.51	245,933

The data upto 1943 obtained from the Annual Report of the River Research Institute, 1951 and the rest calculated by the author.

TABLE 12

Flood	*Run-off in inches*	*Rainfall in inches*	*Run-off in %*
26th to 29th August, 1944	1.68	4.78	35
3rd to 6th August, 1946	0.81	2.15	37
3rd to 5th September, 1947	1.46	4.33	33
21st July to 25th July, 1949	2.00	4.41	45
16th to 20th August, 1949	1.02	3.38	30
17th to 21st July, 1950	1.52	3.32	45
2nd to 6th August, 1950	1.08	3.16	34
11th to 14th August, 1950	1.51	4.20	35

TABLE 13

Statement showing the highest discharge at Rondia and corresponding H.F.L. at different gauge stations along river Damodar.
Highest Flood Level (in P.V.D. Datuam) at.

Sl. No.	Year	Maximum discgarge at Rondia in cusecs.	Rondia	Silan	Guhagram	Jujuty	Jhanpur	Edilpur	Sadarghat	Amirpur	Manikhati	Palla	Serangpur	Jamalpur	Dhapdhara	Jiara	Champa danga	Amta	Gaighata	Remarks
1	1935	7,00,000	178.60	152.18	—	123.33	120.00	111.18	—	—	—	90.04	83.80	79.98	73.84	57.53	48.85	21.60	—	—
2	1936	2,35,006	169.50	148.51	—	120.17	117.92	108.33	—	—	—	90.54	83.06	78.48	69.92	50.49	48.01	21.90		—
3	1937	2,14,000	169.90	147.76	—	120.54	118.50	108.50	—	—	—	90.20	83.14	78.69	70.34	55.53	46.80	21.90		—
4	1938	1,29,550	167.66	143.01	—	119.75	116.50	106.50	—	—	—	88.54	80.56	76.73	67.17	52.53	43.47	19.30		
5	1939	3,20,415	171.20	147.51	—	122.08	119.46	109.50	—	—	—	90.20	83.14	78.31	71.09	57.36	48.63	23.67	23.22	
6	1940	3,80,573	172.50	149.18	—	122.62	119.50	109.04	—	—	—	90.28	83.47	78.65	71.51	56.20	48.88	21.50	19.00	
7	1941	6,50,000	176.00	151.51	—	124.42	120.50	110.87	—	—	—	90.62	84.39	80.06	73.42	58.28	48.72	22.00	19.60	
8	1942	4,45,900	174.60	149.26	—	124.00	119.42	109.20	—	—	—	90.87	83.80	78.90	72.42	56.70	47.97	21.90	20.00	
9	1943	2,25,811	173.30	149.01	—	122.50	118.83	108.75	—	—	—	90.37	83.64	78.90	71.01	55.86	47.22	22.30	18.60	
10	1944	2,19,377	170.50	146.01	133.62	120.67	117.50	108.41	107.41	99.50	97.47	91.54	83.39	78.23	71.26	53.53	48.80	22.60	20.40	
11	1945	1,59,515	169.20	143.01	130.45	117.67	114.32	103.41	103.83	95.91	94.22	88.82	81.04	76.20	67.09	51.11	41.30			
12	1946	3,22,727	172.60	149.48	136.20	122.33	119.00	110.04	110.691	98.95	97.72	91.72	83.44	78.63	71.29	56.78	47.63	23.83	23.50	
13	1947	2,90,199,	172.00	147.91	137.15	121.83	118.42	109.87	106.91	98.28	97.14	91.82	83.64	78.65	70.09	54.61	45.38	21.80	18.20	
14	1948	2,29,671	170.70	146.91	137.65	120.83	120.25	108.83	106.50	97.78	96.59	91.72	83.74	78.33	68.99	53.28	43.22	21.10	17.00	
15	1949	2,71,945	171.60	147.31	134.85	121.25	178.17	109.25	106.41	98.51	95.59	91.02	83.64	78.06	69.34	52.11	41.97	21.50	16.90	
16	1950	3,37,840	172.80	148.51	138.55	121.67	119.33	110.16	107.33	98.88	97.79	91.62	83.24	79.13	69.79	54.45	44.05	23.09	23.10	
17	1951	3,89,131	173.80	148.81	130.45	122.30	119.42	110.33	108.01	98.68	97.09	91.92	83.84	79.13	70.49	54.86	46.05	21.90	18.80	
18	1952	1,80,909	169.60	145.51	132.65	118.67	116.25	107.08	104.91	96.68	95.79	90.42	82.64	77.63	67.39	52.95	41.80	20.40	15.90	
19	1953	2,92,834	172.00	148.01	137.25	122.25	119.17	110.04	107.75	99.38	97.89	92.51	83.74	78.73	70.19	54.94	45.05	22.23	19.90	
20	1954	2,61,736	171.40	146.71	133.85	120.75	118.17	109.38	106.88	98.38	97.49	91.92	84.54	78.73	69.09	53.03	43.20	21.70	17.20	

TABLE 14

Flood.

21-31 *August* 1953.

Site.	*Rate of peak flow in Cusecs*	*Time observed*	*Peak flow*
Rhondia	2,92,834	2 P.M.	24.8.53
Mohiddipur	49,218	5 P.M.-3.45 P.M.	24.8.53
Do Damodar	23,775	6 A.M.-6.15 A.M.	25.8.53

Maximum flow has passed Mohiddipur at night hence the discrepancy. It must have been of the order of 200,000 cusecs ?

7th-20th September 1953.

Rhondia	95,205	6 a.m.	11.9.53
Mohiddipur Kaki	44,722	5 p.m.	11.9.53
Do Damodar	7,546	4.45 p.m.	11.9.53

7th-30th September 1954.

Rhondia	2,61,736	4 a.m.	8.9.54
Mohiddipur Kaki	1,81,981	11 a.m.	8.9.54
Do Damodar	21,654	2 p.m.	8.9.54

TABLE 15

For 1954 Floods

Flood 7th to 30th September, 1954

(*Figures are approximate*)

	Volume of discharge in acre ft.	*Peak Flow in Cusecs.*
Rhondia—Damodar	2,355,348	261,736
Mohiddipur—Kaki	1,941,382	181,961
Damodar	98,324	21,654
Total :	2,039,707	203,635
Difference with Rhondia	413,962 ac.ft.	(loss 17.6%)
Estimated flow through Hanas at the peak flow.	....	56,170
		259,805 Cusecs.

TABLE 16

1952 Floods

(1) 17*th August*, 6.*P.M. to* 25th *August* 6 *P.M.*

River	*Station at.*	*Volume in Acre ft.*
Damodar	Damodar Bridge Site	3,50,394.031
,,	Rhondia	5,74,582.410
,,	Jamalpur	2,77,646 650

(2) 5*th September* 6 *A M. to* 16*th September* 6*P.M.*

River	*Station at*	*Volume in Acre Ft.*	
Damodar	Damodar Bridge Site	5,96,883.894	
Malandighi	Malandighi	20,251.086	
Singaran	Singaran	1,862.590	27,745.451
Tumla	Tumla Bridge Site	5,631.775	
Damodar	Rhondia	9,68,009.172	
,,	Jamalpur	3,71,749,240	

TABLE 17

1953 Floods

River	*Station at*	*Volume in Acre Ft.*
Damodar	Damodar Bridge Site	11,55,759
,,	Rhondia	16,34,033
,,	Mohiddipur	54,463
Kaki	,,	7,34,290

(4) *September 7th* 10 *A.M. to 20th September* 10 *A.M.*

River	*Station at*	*Volume in Acre Ft.*
Damodar	Damodar Bridge Site	8,40,158.904
,,	Rhondia	15,70,587.237
,,	Mohiddipur	95,214.149
Kanki	,,	6,93,436.978

TABLE 18

Sl. No.	*Name of Hana*	*River levels at which hana spills (P.W.D) (i.e. av. bed level of the Hana).*	*Remarks.*
1.	Panchapara	125.68	
2.	Kumirkhola	119.00	Controlled by regulator
3.	Bhasna	123.63	
4.	Gurpur	108.40	
5.	Gaitanpur	108.31	
6.	Barasat	101.47	
7.	Jakta	96.97	
8.	Mohanpur Hana	90.00	Controlled by Weir
9.	Jamda	83.77	
10.	Nagra	81.50	Controlled by Regulator
11.	Krisnapur	79.00	

TABLE 19

Year.	Rondia gauge		Area flushed			Remarks.
	Maximum Flood level.	Maximum discharge. in Cusecs.	Area above Muchi Hana.	Area below Muchi Hana.	Total area.	
1935	178.60	7,00,000	188	274	462	
	(P.W.D).	Cusecs.	Sq. Miles.	Sq. Miles.	Sq. Miles.	
1941	178.00	6,50,000	183 ,,	264 ,,	447 ,,	
1942	174.60	4,45,900	164 ,,	252 ,,	416 ,,	
1951	173.80	3,89,131	144 ,,	239 ,,	383 ,,	
1953	172.00	2,92,834	130 ,,	230 ,,	360 ,,	
1944	170.50	2,19,377	102 ,,	221 ,,	323 ,,	
1938	167.60	1,29,550	79 ,,	204 ,,	283 ,,	

TABLE 20

Year.	Maximum Flood discharge at Rondia (in Cusecs)	Peak-discharge of Sali Nadi (in Cusecs)	Total discharge (in Cusecs)	Damodar discharge above Cusecs)	Discharge spilling over right bank above Kaki river or Muchi Hana (in cusecs)
1935	7,00,000	50,643	7,50,643	76,068	6,74,035
1941	6,50,000	,,	7,00,643	73,235	6,27,408
1942	4,45,900	,,	4,96,543	61,401	4,35,142
1951	3,89,131	,,	4,39,774	49,764	3,90,010
1953	2,92,834	,,	3,43,477	43,725	2,99,752
1944	2,19,377	,,	2,70,020	48,861	2,21,159
1938	1,29,550	,,	1,80,193	61,395	1,18,798

TABLE 21

Year	Discharge of Damodar river at Mohanpur (in cusecs)	Discharge at Madaria Khal (in cusecs).	Total Discharge (in cusecs)	Discharge of Damodar river at Amta (in cusecs)	Discharge spilling over right bank below Kaki river (in cusecs)
1935	24,342	11,450	35,792	10,855	24,937
1941	21,413	—do—	32,863	11,827	21,036
1942	14,135	—do—	25,585	10,963	14,622
1951	6,932	—do—	18,382	10,674	7,708
1953	8,546	—do—	19,996	10,898	9,098
1944	13,390	—do—	24,840	10,678	14,162
1938	3,749	—do—	15,199	5,933	9,266

TABLE 22

Year.	Mixmum discharge of the Damodar at Rondia (in cusec)	Maximum discharge of the Damodar above Muchi Hana (in cusec)	Discharge of the Damodar below Muchi Hana at Mohanpur in (cusec)	Discharge passing through Kaki river in cusecs.	Percentage of discharge passing through Main Damodar river (lower reach)	Kaki river.
1935	7,00,000	76,608	24,342	52,266	32%	68%
1941	6,50,000	73,235	21,431	51,804	29%	71%
1942	4,45,900	61,401	14,135	47,266	23%	77%
1951	3,89,131	49,764	6,932	42,832	15%	85%
1953	2,92,834	43,725	8,546	35,179	20%	80%
1944	2,19,377	48,861	13,390	35,471	29%	71%
1938	1,29,550	61,395	3,749	57,646	6%	94%

TABLE 23

Discharge of the River Damodar above Muchi Hana at differert H.F.L's

Year	H.F.L. (P.W.D.) datum.	Sectional area in Sft.	Velocity in ft/sec.	Discharge in cusecs	Remarks
1935	75.00	25,200	3.04	76,608	
1941	74.70	24,250	3.02	73,235	
1942	73.70	21,100	2.91	61,401	
1951	72.50	17,400	2.86	49,764	
1953	72.00	15,900	2.75	43,725	
1944	72.80	18,300	2.67	48,861	
1938	69.00	11,650	5.27	61,395	

TABLE 24

Discharge of the river Damodar at Mohanpur at different H.F.L's.

Year.	H.F.L. (P.W.D.) Datum.	Sectional area in S/ft.	Velocity in ft./sec.	Discharge in in cusecs.	Remarks
1935	67.60	9362.31	2.60	24,342	
1941	67.40	8959.71	2.39	21,413	
1942	66.20	6574.71	2.15	14.135	
1951	64.00	3348.68	2.07	6,932	
1953	64.90	4437.51	1.92	8,546	
1944	64.50	3892.31	3.40	13,390	
1938	61.50	1856.26	2.02	3,749	

TABLE 25

Discharge of the river Damodar at Amta at different H.F.L's.

Year.	*H.F.L. (P.W.D.) Datum*	*Sectional area in S/ft.*	*Velocity in ft/sec.*	*Discharge in cusecs.*	*Remarks.*
1935	21.60	3947.49	2.75	10,855	
1941	22.00	4179.49	2.83	11,827	
1942	21.90	4121.49	2.66	10,963	
1951	21.90	4121.49	2.59	10,674	
1953	22.25	4324.74	2.52	10,988	
1944	22.10	4237.49	2.52	10,678	
1938	19.30	2829.49	2.09	5,933	

TABLE 26

Year—1951.

Month	*Date*	*Recorded flow at Rhondia.*	*No of floods above 50,000 cusecs*
July	6.7.51 to 7.7.51	1,07,409 cusecs	2
	12.7.51 to 13.7.51.	83,256 ,,	
August	17th to 19th.	74,725 ,,	1
September	7.9.51	53,723 ,,	2
	11.9.51	3,89,131 ,,	
October	Nil.		

Discharge in the Hanas during above flood occasions.

Sl. No.	*Name of Hanas.*	*Approx. discharge in cusec during floods on*				
		6.7.51 to 7.7.51	12.7.51 to 13.7.51.	17.8.51 to 19.8.51.	7.9.51.	11.9.51.
1.	Panchpara	2506	1620	2038	1412	4184
2.	Bhasha	346	120	330	190	1512
3.	Kumirkhola	closed by cross bands.				Controlled by Weir.
4.	Gurpur	2344	2340	1980	1506	3520
5.	Gantanpur	1532	960	1310	832	3248
6.	Barasat	2856	804	2640	1536	7684
7.	Jakta	1470	416	1320	200	2676
8.	Mohanpur	14897	5433	9978	1750	40909 Controlled by Weir.
9.	Jamda	1960	1626	1900	1264	3112
10.						642 Controlled by Rgulator.
11.	Krishnapur					514

TABLE 27

Year 1952.

Month	*Date.*	*Record flow at Rhondia.*	*No of floods above 50,000 cusecs*
June			
July	(*a*) 5th to 6th	51,957 Cusecs	2
	(*b*) 26th, 27th	1,80,909 ,,	
August	(*a*) 20.8.52	46,509 ,,	2
	(*b*) 22.8.52	53,106 ,,	
September	(*a*) 11th, 13th	1,69,891 ,,	2
	(*b*) 23rd to 25th	66,631 ,,	
October	(*a*) 11.10.52	55,983 ,,	1

Discharge in the Hanas during above floods.

Name of Hana	*Approx. discharge in cusec during floods on*						
	5th to 6th July	*26th to 27th July.*	20.8.52.	22.8.52	*11th to 13th September*	*23rd to 25th September*	11.10.52
Panchpara		2644	1932		2172	1908	
Bhasna		526	342		388	288	
Kumirkhola	Closed by cross bundh					Controlled by weir	
Glurpur	764	1300	886	856	1168	1036	1296
Gautampur	786	1992	1320	1016	1690	1434	912
Barasat	2010	3728	2460	2014	3268	2870	1888
Jakta	728	1238	810	562	1060	906	540
Mohonpur	300	2028	9300	2952	14028	9500	590
Jamda	1216	2594	1858	1612	2312	2070	Controlled by weir. 1092
Lakhra		20				Controlled by regulator	
Krishnapur							

TAB

Year

Month	*Date*	*Record flow*
June		
July	(*a*) 4th to 15th	2,28,688
	(*b*) 18th to 19th	51,016
	(*c*) 28th to 30th	77,016
August	(*a*) 4th to 6th	89,856
	(*b*) 12th to 13th	68,839
	(*c*) 15th to 18th	83,705
	(*d*) 20th to 30th	2,92,834
September	(*a*) 10th to 12th	93,205
	(*b*) 14th to 15th	80,625
	(*c*) 17th to 20th	85,349
	(*d*) 28th to 30th	1,69,220
October		

Sl. No.	*Name of Hana*	*Approximate Discharge*				
		4th-15th July	*18th-19th July*	*28th-30th July*	*4th-6th Aug.*	*12th-13th Aug*
1.	Panchpara	3374	2290	2400	2584	2434
2.	Bhasna	616	338	362	410	270
3.	Kumirkhola	Closed	by	cross	bundhs	
4.	Gurpur	4430	3262	3140	3538	3398
5.	Gautampur	2156	1434	1458	1602	1462
6.	Barasat	4040	2964	2972	3096	2956
7.	Jakta	1360	974	968	690	590
8.	Mohanpur	29983	17298	16398	19143	16075
9.	Jamda	2054	2272	2258	2380	2240
10.	Lakra	197				
11.	Krishnapur					

TABLE 28

Year 1953.

cord flow of Rhondia	*No. of flood above 50,000 Cusecs.*
2,28,688 Cusecs.	3
51,016 ,,	
77,016 ,,	
89,856 Cusecs.	4
68,839 ,,	
83,705 ,,	
2,92,834 ,,	
93,205 Cusecs	4
80,625 ,,	
85,349 ,,	
1,69,220 ,,	

	in cusecs		*during*	*floods*		*on*	
-13th Aug	*15th-18th Aug.*	*20th-30th Aug.*	*10th-12th Sept.*	*14th-15th Sept*	*17th-20th Sept.*	*28th-30th Sept.*	*Remarks*
434	2400	3732	2258	2500	2700	3068	
270	362	1552	324	360	428	526	
		16331	4758	5289	7253	9758	C.B.W.
398	3140	4938	3250	3250	3548	3824	
462	1458	2504	1420	1470	1568	1732	
956	2972	4524	2952	1672	3040	3544	
590	968	1564	942	882	1002	1164	
075	16398	38829	16700	14464	15427	21334	C.B.W.
240	2258	3152	2240	2028	2510	2674	
		403					C.B.W.
		678					

TABLE 29

Year 1954.

Month.	*Date.*	*Recorded flow at Rhondia.*	*No. of floods above 50,000 cusecs*
July	30.7.54	62,951 Cusecs.	1
August	(*a*) 8th to 19th	56,652 ,,	2
	(*b*) 21st to 22nd	93,839 ,,	
September	(*a*) 8th to 11th	2,61,736 ,,	2
	(*b*) 17th to 20th	66,068 ,,	

Discharge in the Hanas during above flood occasions.

Sl. No.	*Name of Hana.*	*Approx. discharge in cusecs during floods on*					
		29th-30th July	*8th to 19th August.*	*21st-22nd August.*	*8th to 11th September.*	*17th to 20th September*	
1.	Panchpara	2310	1628	2708	3718	2232	
2.	Bhasna	348	246	472	1194	252	
3.	Kumirkhola			5317	13664		
4.	Gurpur	1724	1574	2012	2840	1592	
5.	Gautampur	1468	1156	1932	3180	1182	
6.	Barasat	1936	1610	2470	6822	1634	
7.	Jakta	664	480	1478	2346	534	
8.	Mohonpur	5882	2358	12858	32112	2564	C.B.W.
9.	Jamda	1652	1304	3304	4628	1380	
					114		C.B.R.

TABLE 30

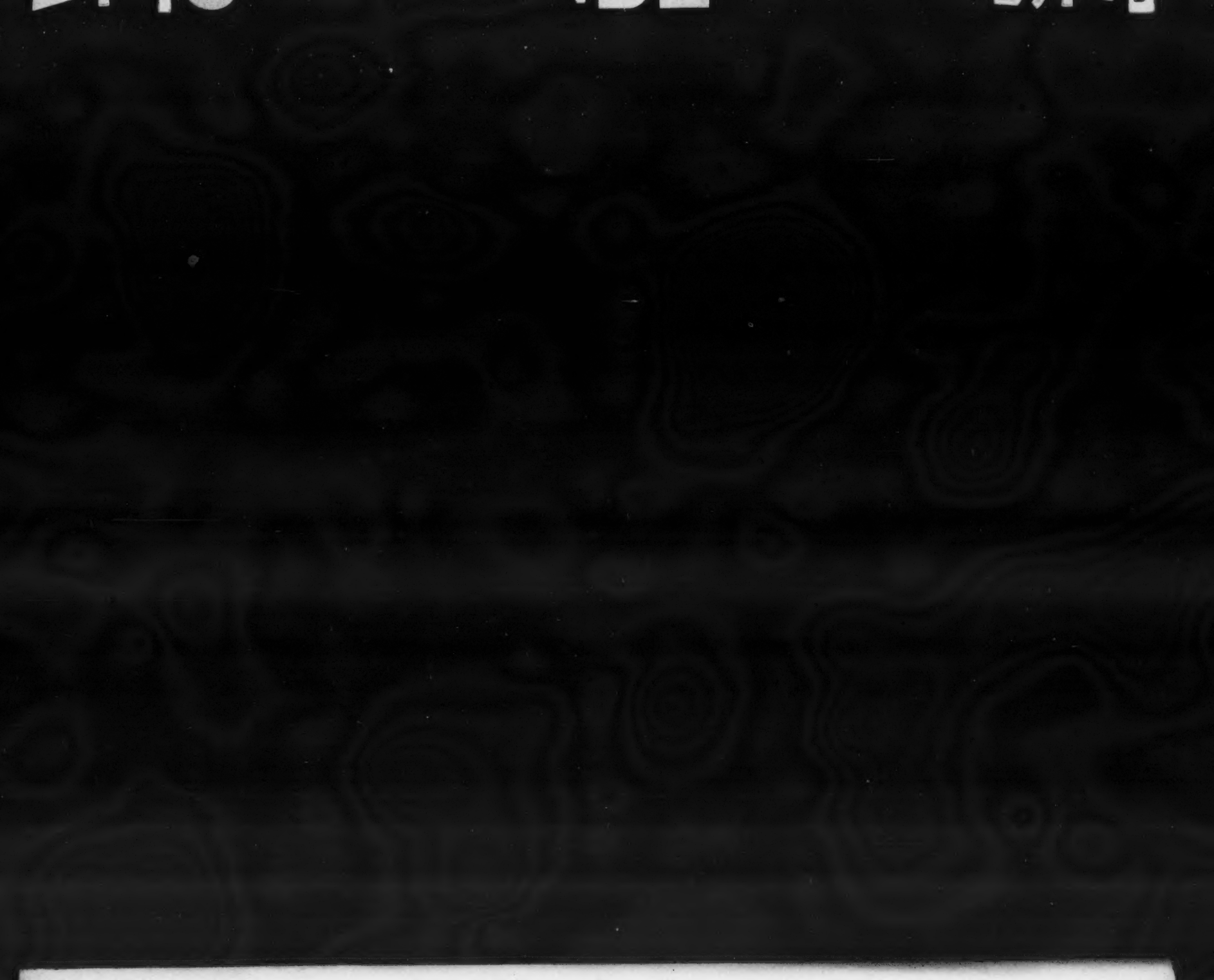
Year 1955.

Month.	*Date.*	*Record flow at Rhondia.*	*No. of floods above 50,000 cusecs.*
June			
July	28.7.55	58,663 Cusecs	1
August	13.8.55	52,479 ,,	1
September			
October			

Discharge in the Hana during above flood occasion.

Sl.	*Name of Hana.*	*Approx. discharge in cusecs during floods on* 28.7.55	13.8.55.	*Remarks*
1.	Panchpara			
2.	Bhasna			
3.	Kumirkhola			C.B.W.
4.	Gurpur	826	534	
5.	Gautampur	106	126	
6.	Barasat	658	476	
7.	Jakta	304	30	
8.	Mohanpur			C.B.W.
9.	Jamda			
10.	Lakra			C.B.W.
11.	Krishnapur			

N.B. Table 18 to 30: These tables and data have been received by the author from Damodar Canal Division, Burdwan. The author is very grateful to the authorities for receiving the data and utilising it.



Location of Hana.	*Depth*
Hana at Gautampur	5.40
	4.60
	1.20
	3.98
	2.55
	.55
Hana at Barasat	10.30
	5.15
	1.60
Hana at Jakta	9.60
	7.00
	5.97
	5.32
	5.20
	1.84
Hana at Nagra	6.45
	4.20
	3.60
	2.40
	.25
Hana at Jamda	10.80
	9.60
	8.20
	7.03
	4.98
	3.88
	1.08
Hana at Mohanpur	19.00
	15.80
	13.94
	13.60
	11.50
	7.90
	1.73
Hana at Gauripur	10.00
	6.20
	5.18
	4.25
	3.00
	2.03
Hana at Kumirkhola	9.60
	8.60
	6.59
	4.75
	4.75
	4.20
	.81
Hana at Bhasna	12.00
	10.20
	9.40
	9.33
	6.60
	2.50
Hana at Panchpara	20.20
	19.00
	15.00
	9.38
	7.55
	1.17

TABLE 31
Year 1953.

epth	*Discharge in cusecs.*	*Slopes at different position of Hanas* (1953)
5.40	1,050	
4.60	840	
1.20	120	.00013
3.98	282	
2.55	124	
.55	38	
10.30	1,762	
5.15	417	.00016
1.60	44	
9.60	750	
7.00	600	
5.97	327	.00034
5.32	224	
5.20	450	
1.84	22	
6.45	792	
4.20	526	.00043
3.60	375	
2.40	240	
.25	4	
10.80	3,550	
9.60	3,950	
8.20	3,150	.00033
7.03	704	
4.98	420	
3.88	159	
1.08	22	
19.00	22,620	
15.80	20,100	
13.94	25,777	.00040
13.60	16,320	
11.50	16,934	
7.90	7,962	
1.73	20	
10.00	1,545	
6.20	780	.00026
5.18	586	
4.25	163	
3.00	240	
2.03	25	
9.60	closed by bund	
8.60	4,905	
6.59	3,039	.00013
4.75	2,003	
4.75	2,003	
4.20	closed by bund	
.81	52	
12.00	849	
10.20	639	
9.40	127	.00013
9.33	109	
6.60	294	
2.50	19	
20.20	50,250	
19.00	44,250	
15.00	17,250	.00040
9.38	1,134	
7.55	794	
1.17	35	

	JUNE		JULY	
	Silt in area ft.	*Discharge in acre ft.*	*Silt in acre ft.*	*Discharge in acre ft.*
1953				
Damodar Bridge site	95,822	902.138	902.138	20,95,644
Mohiddipur (Damodar)	observation from 14/7.	started	46.488	64,392
"Kanki) ,,			522.338	8,35,140
1954.				
Damodar Bridge site	149.824	2,92,154	384.320	6,71,916
Mohiddipur (Damodar)				
Mohiddipur (Kanki)	7.546	92,782	307.706	5,18,432
1955.				
Damodar Bridge Site (Damodar	13.082	85,236		
Surekalna (Damodar)				
Muchi Hana				
Begua Hana				
Mohiddipur (Damodar)				
Harin Khola (Mumdeswari)	3.64	38,886	77.08	10,90,13
Mayapur (Kabla W.)			11.68	33,974
Santara (Harinkhal)			49.22	71,210

TABLE 32

	AUGUST		SEPTEMBER		OCTOBER	
rge in ft.	*Silt in acre ft.*	*Discharge in acre ft.*	*Silt in acre ft.*	*Discgarge in acre ft.*	*Silt in acre ft.*	*Discharge in acre ft.*
95,644	740.186	22,96,938	488.430	16,13,038	33.276	2,60,396
64,392	170.879	2,38,320	86,592	1,54,610	34.416	1,22,980
35,140	1024.314	19,63,098	523.114	11,62,948	53.356	3,60,680
,71,916	448.924	8,92,214	473.178	12,64,360	35.380	1,78,938
	19.050	31,612	65.506	98,322		
18,432	413.196	8,67,934	2869.788	20,17,946	26.518	2,68,306
	299.20	6,57,726	63.68	2,87,178	72.04	3,08,576
,90,13	821.58	10,75,968	64.46	3,14,392	28.92	1,64,278
3,974	10.36	25,696—No Velocity, no discharge in the stream, stagnant water.				
71,210	23.40	61,984—Sample not collected—River water stagnant.				

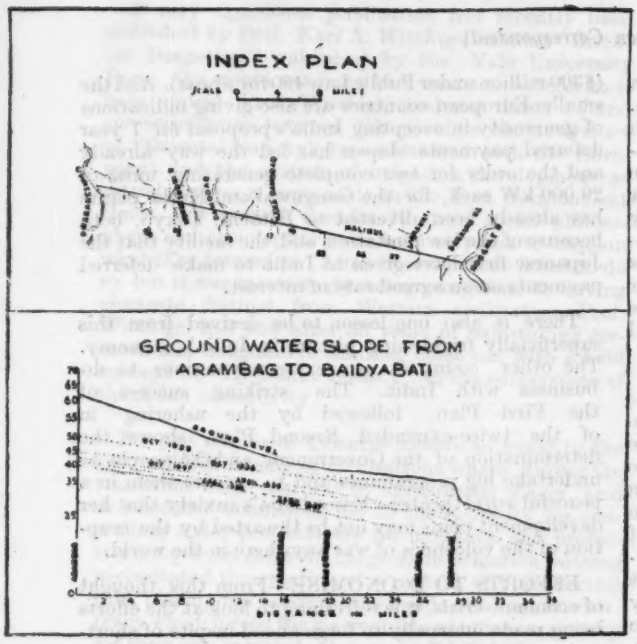


Fig. 49

Fig. 50

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Our Delhi Letter

(From our own Correspondent)

The month of June, 1957 may well be regarded as a near-crisis period for the Second Five Year Plan. The Capital is giving evidence of this belief in many ways. The Secretariat is prepared for announcement of austerities in a dozen forms. Whether it is the non-filling of vacant posts in the Finance Ministry or the setting up of economy teams in the Community Projects, Buildings or the Irrigation and Power Projects, or the announcement of voluntary salary cuts by the Speaker of the Lok Sabha, or the President, or the Vice-Chairman of the Planning Commission, the atmosphere is being continually charged with zeal and concern for economies in the Public Sector.

The decision of the Prime Minister to shift to a smaller house (still to be built), and the sympathetic decisions in other State capitals of the abandonment of important public buildings like the Punjab Vidhan Sabha, the Kulapati Bhavan or the grand air-conditioning proposals for the Secretariat, all confirm the rigid and firm policy of the Government for crying a halt to creation or expansion of luxuries. There is no doubt some comment by the public on the adequacy or the efficacy of any or all of the above measures, but the symbolic value of the decisions is bound to appeal to the imagination of the masses. After all, any sacrifice still remains a sacrifice even though the habitually carping minds may refuse to be satisfied by their scope and incidence.

But even in the best informed circles, doubts have been expressed as to whether the gaps in our economy (foreign exchange as well as rise in the prices of food) will get bridged in time. The economists are baffled about the extent of the deflation that has already taken place in our reserves and they are also sceptial about the availability of foreign loans in a big enough measure to be of substantial help in the execution of the Plan Projects. They are concerned about the failure of the Agricultural Sector which has not risen to the occasion unlike in the First Five Year Plan when food production showed an increase of 20%. And in India, the economy is completely dependent and utterly sensitive to the price rise of food grains, whether it be rice or wheat.

All eyes are, in such circumstances, looking at the skies to give a timely and plentiful monsoon. There again, one has to talk in cautious terms because the experience of too heavy rains and consequent floods is yet too green and ghastly in the public memory. All told, the picture is one of suspense and foreboding, and yet the people (and the Government circles) are hoping that the difficulties will solve themselves. They feel that if we remain steadfast in our resolutions and actions to implement the Plan, help is bound to come from all sides.

LOANS FROM OTHER COUNTRIES

And this expectation is not altogether unjustified, as the newspapers are discussing possible loans of big magnitude from Britain (£100 million) and U.S.A. ($300 million under Public Law 480 for wheat). And the smaller European countries are also giving indications of generosity in accepting India's proposal for 7 year deferred payments. Japan has led the way already and the order for two complete generating units of 29,000 kW each, for the Ganguwal and Kotla plants has already been diverted to Hitachi, Tokyo, both because of the low quotation and the facility that the Japanese firm have given to India to make deferred payments on an agreed rate of interest.

There is also one lesson to be derived from this superficially frightening picture in India's economy. The other countries are extremelyanxious to do business with India. The striking success of the First Plan, followed by the ushering in of the twice-expanded Second Plan, shows the determination of the Government and the people to undertake big programmes and to execute them in a peaceful world theatre—hence India's anxiety that her development plans may not be thwarted by the eruption of the volcanoes of war anywhere in the world.

EFFORTS TO ECONOMISE—From this thought of economic crisis, it is refreshing to look at the efforts being made internally to forge ahead inspite of shortages and difficulties. As to cement and steel, the Irrigation and Power Ministry have just announced their preference for the use of lime instead of cement and of the old type of construction, using arches instead of reinforced concrete slabs. Planners of projects have been asked to exercise utmost economy in their designs as well as modes of construction. That the call has been made none too soon, is apparent from the acute shortage of steel and cement for which various projects are competing in an atmosphere of overall serious shortage. But the silver lining in the whole affair is the availability in India of large numbers of skilled workers, who have done arch masonry construction in lime and mortar, and who have the requisite knowledge and skill today to give a reorientation to the architecture and construction techniques with only a reasonable amount of readjustment, which will not jeopardize safety or even quality.

PLANNING COMMISSION ADOPTS NEW YARDSTICK—The effect in the sanctioning of the Projects from State Governments by the Planning Commission is specially noteworthy. Since there is an urgent need for conserving foreign exchange as well as rupee capital, the yardstick of ultimate economy through single stage construction of large projects is being somewhat modified. The amount of initial investment in the first stages of a multi-stage project is now receiving an all-out importance. In other words, even if the concurrent construction of the civil works of a large powerhouse is justifiable on the basis of economical considerations, the 2nd and 3rd stages are now regarded as postponable because the country cannot afford to have its limited resources exhausted over a smaller number of projects. The argument prevailing is to spread the benefit over as

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Hydraulic Society?

A very significant publication has recently been published by Prof. Karl A. Wittfogel entitled "Oriental Despotism" published by the Yale University Press. We would not have had occasion to refer to it here unless Prof. Wittfogel had not dared to find correspondence between the peculair characteristics of "Oriental Society" (as contrasted with the European) and the system of irrigation development as introduced on a large scale in the East from ancient times. For several decades Western social philosophers and sociologists have been at pains to explain what they termed as "Asian Society" but failed to do so, but it was increasingly being recognised as having elements distinct from Western civilization. Prof. Wittfogel has now after 35 years of painstaking research and imaginative thinking come out with a bold concept of "Hydraulic Society" as the cornerstone of the Asian commur ity.

For the origins of Oriental society he turns to the geographical setting of civilisations where, during the transition from pastoral to agricultural stages, arid or semi-arid conditions led to the necessity for controlling water productively for irrigation and protectively for flood control. Large-scale irrigation farming necessitated the creation of a pattern of bureaucratic rule, placing full power in the hands of a vast bureaucracy which forced the masses to do what was necessary for their own survival. Once consolidated, these bureaucracies moved beyond the immediate hydraulic tasks into other activities which tended to symbolise and enhance their power, huge defence structures, roads, palaces, temples, etc. Society became stratified into two groups : the bureaucratic rulers and the masses who were ruled. Wittfogel finds common structural patterns in the agrarian civiliasations of such widely scattered areas as Egypt, Mesopotamia, India, Persia, Central Asia, South-East Asia, Hawaii, and even Meso-America. Because the classical English economists from whom he draws much inspiration used the term "Oriental society" to describe the great despotisms in the East, he accepts their term as interchangeable with "hydraulic society," but he prefers the latter because it describes a specific institutional conformation which is not necessarily limited by geography.

Wittfogel finds that hydraulic society "dwarfed all other agrarian societies in dimension and institutional diversity." (Dimension here means durability, extent of power, and the size of the population dominated.) He therefore gives meticulous attention to developing and defining the various sub-types of this social structure both in terms of internal organisation and environment, supporting his analysis with a wealth of illustrative material. The result is a comprehensive picture of a societal type which until now has been little understood, and the significance of which we would ignore at our peril in the world to-day.

In successive chapters Wittfogel points out that the hydraulic economy is completely managerial and completely political (chapter 2), that the state is always stronger than society (chapter 3). For the "monopoly bureaucracy" there is an absence of effective checks on total power. In some states such as traditional China, a looseness of bureaucratic control allowed politically insignificant forms of association such as family, village, guild, and religion to play a secondary role (chapter 4), but the hydraulic society tended toward total power, total terror, total submission, and total loneliness (chapter 5). He discusses the interrelationships of hydraulic societies with surrounding areas and the transmission of techniques of bureaucratic control from one area to another over the historical past (chapter 6).

The treatment of the subject by the learned author is highly original and thought-provoking, though challenging. We strongly recommend our engineers to go through this very important publication, not only because it interprets our past in a particular way but it also by implication indicates to us that the present large-scale basin-wise water management and irrigation projects tend to perpetuate the pre-conditions of "original despotism" of the past which we are trying to live out as fast as possible.

* * *

Aswan Dam

Now that the Suez crisis has almost been solved, at least in it explosive political aspects, it is time that greater constructive attention is given to the building of the Aswan Dam, the issue which has sparked the major trouble. We are not yet sure if the £ (E) 16 millions would be available annually from the Suez Canal income for use in the Aswan Project, but if this is even roughly true, as is claimed to be, it is high time that the Project is finalised to the statisfaction of all interested States such as the Sudan, Ethiopia and Uganda. As we had occasion to remark earlier in this connection, a satisfactory solution of this issue is of basic significance, although this aspect had been considerably ignored or sidetracked due to the heightened political strains resulting from the Suez episode. In the interests of the teeming millions of peasants and proverty-stricken masses inhabiting this area, the earlier the project is taken up the better. If approached in the right spirit, it may not now even be difficult for international monetary agencies to come to the aid of the authority which will have direct responsibility for its execution.

* * *

New Central Cadre

We are extremely happy to note that the Government of India is creating a new Central carde to look after the projects that are being undertaken by Ministries in the economic field. A certain degree of specialisation has now become inevitable in the Administrative Cadre. But it appears from the press reports that the selection for this Cadre is restricted to only from the Indian Admisistrative Cadre. As we had pointed out earlier (editorial March, 1957), able and experiencend engineers and scientists who have shown their mettle in the administrative task should also be eligible for inclusion in the new cadre. This is necessary on the ground of the need of the different projects as also on the psychological ground. The Administrative Service is supposed to be a pool of our best administrative talents. But this may not always be the case. On the other hand, there may be really competent administrative hands among the specialists and engin-

eers who might after all fit in better in units and responsibilities which require not only a "pure" administrative capacity and aptitude but also a certain background of technical knowledge and experience. If we do have such persons, as we are sure we have, it would be unfair not to select them and it would also not be conducive to the furtherance of the basic purpurpose of the creation of the new cadre, namely, to facilitate administration of economic projects that are or likely to be taken in hand in the country.

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Our Delhi Letter

large an area as possible and later on to let the beneficiary states expand the scope of the projects just ahead of the development of the power market. This philosophy is analogous to any prudent man trying to tide over the period of his economic limitations by restricting himself to the bare minimum amount of necessities and amenities. That these will be able to be enlarged in course of time is taken for granted.

Minor Projects for Food Production

The maximum importance attaches now to such projects which need a minimum of foreign exchange quota, and have a maximum benefit/cost ratio in terms of food production. This opens the field for minor projects and other small projects where the assets already exist and small extensions and improvements lead to relatively big results. This is the silver lining in an otherwise difficult horizon, which is bound to clear sooner than some pessimists would have one believe.

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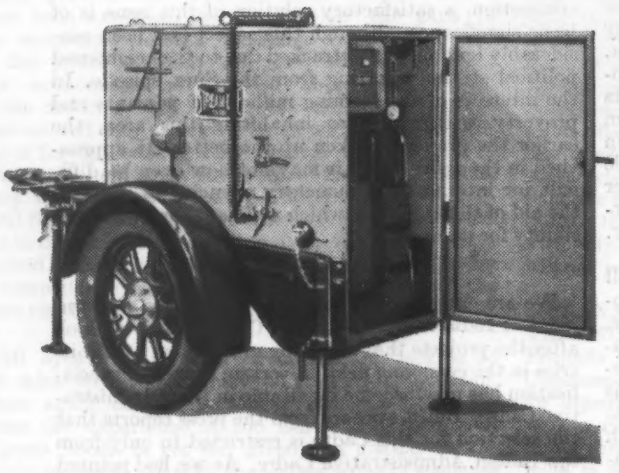

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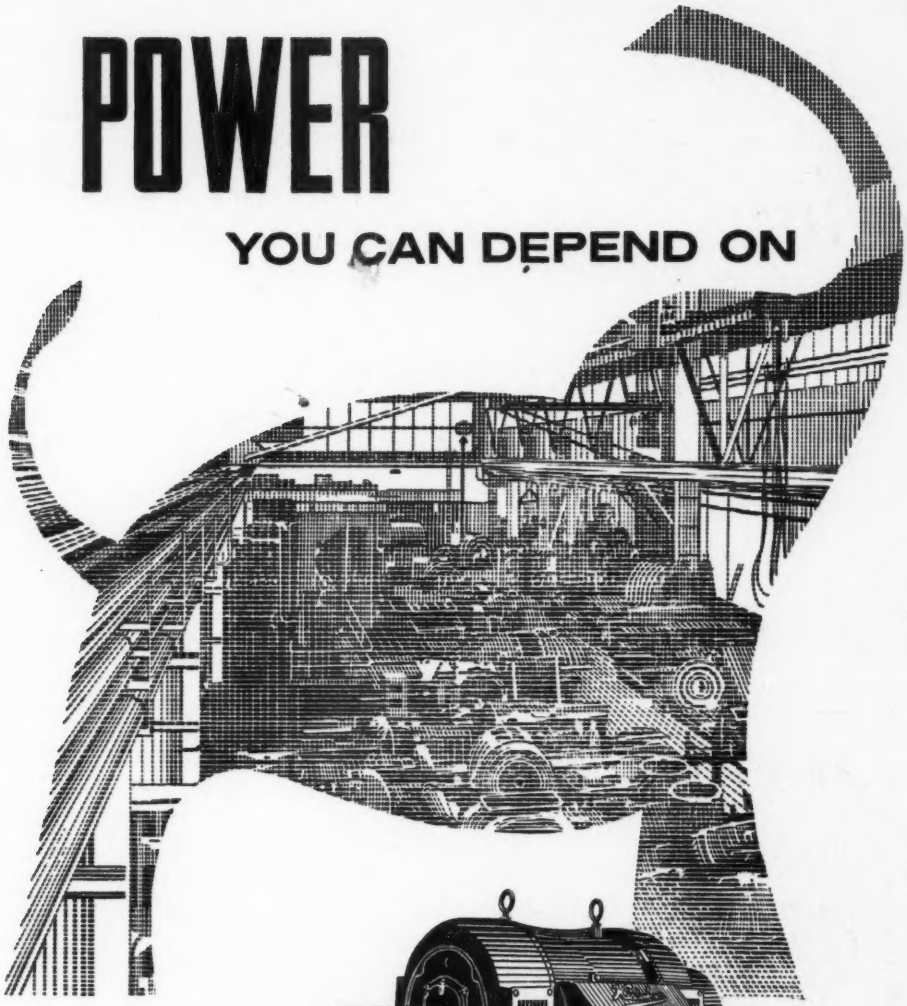

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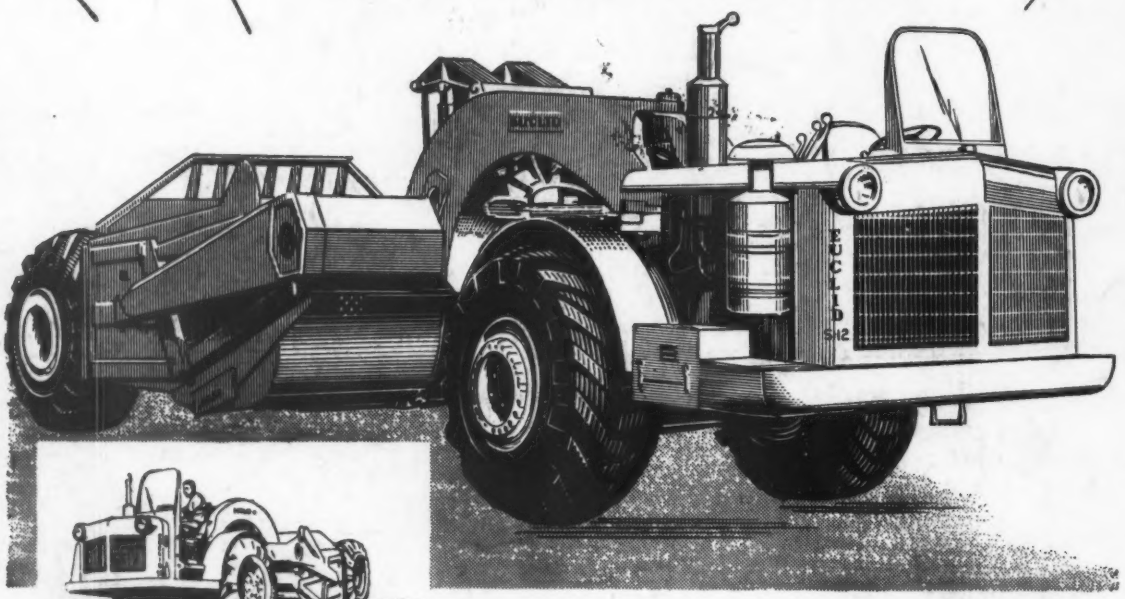

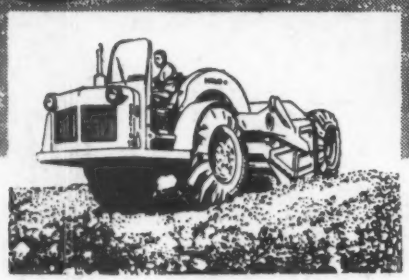

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